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Iowa Greenhouse Gas Action Plan



Prepared by The University of Iowa for the
Iowa Department of Natural Resources
Larry J. Wilson, Director
December, 1996

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DISCLAIMER

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Executive Summary

Water vapor, carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons are among the atmospheric constituents known as greenhouse gases. Greenhouse gases allow short wave radiation from the sun to reach the planet but long-wave back-radiation cannot leave the atmosphere, thus adding heat energy into the earth-atmosphere system. The resulting energy balance allows a portion of the solar radiation to remain trapped within the earth-atmosphere system - "a greenhouse". Human activities could be impinging on natural climate systems. Buildup of gases in the atmosphere, caused primarily by burning fuels for energy, may lead to global changes in climate. A changing climate could have a major impact on Iowa's agriculture, as well as water supply and energy demand.

To further the study of greenhouse gas emissions emanating from the states, the U.S. Environmental Protection Agency developed a program, the Global Climate Change Outreach Program, which provides funds for conducting a three-phase approach to reducing greenhouse gas emissions. Phase I is the standardized baseline inventory of greenhouse gas emissions. Phase II is the development of a state action plan for greenhouse gas emissions reduction. This Iowa Greenhouse Gas Action Plan represents Iowa's Phase II effort. Phase III involves evaluation and documentation of the emission reduction strategies from Phase II.

The Iowa Greenhouse Gas Action Plan provides a strategy for investment in the Iowa economy while mitigating current and future greenhouse gas emissions. The Iowa Greenhouse Gas Action Plan contains options that can strengthen Iowa's economy by diversifying agricultural production, raising new energy crops, increasing sales of energy efficient appliances, generating renewable fuels, and increasing competitiveness in manufacturing. Investment in energy efficiency and renewable resources produces positive economic results and reduces greenhouse gas emissions. Resources committed to protecting Iowa's environment from greenhouse gases should not be viewed as a cost, but as an investment that has current and future economic development benefits.

Iowa is the fifteenth highest emitter in the U.S. for greenhouse gases per capita (see Summary Tables in Appendix C). Considering all sectors of the economy, Iowa emits 29 tons of carbon dioxide per person annually. Iowa can save money and limit pollution by increased energy efficiency and decreased carbon dioxide emissions. In the absence of an Iowa Greenhouse Gas Action Plan, baseline emissions are projected to increase 18.5 percent between 1990 and 2010. The U.S. goal is to decrease greenhouse gas emissions to 1990 levels by 2000, and to accomplish further reductions by 2010. Implementation of the Priority Options in this Action Plan will ensure that Iowa meets the goal of reducing its carbon dioxide emissions to 1990 levels by 2000. Eighty-seven million tons of carbon dioxide (equivalents) per year would be reduced to 84 million tons per year by the Priority Options in the Iowa Greenhouse Gas Action Plan by 2010.

The Iowa Greenhouse Gas Action Plan is built on a combination of energy efficiency programs and renewable energy initiatives. It discusses a total of 34 options for reduction of greenhouse gas emissions (carbon dioxide, methane, and nitrous oxide), of which 16 are selected as the most cost-effective and easily achievable. While reduction of greenhouse gas emissions is a difficult task, *this plan discusses policy options that may be pursued to assist the state in making those reductions possible, with a positive impact on Iowa's economy and environment.* Summary Table A lists the policy options recommended in the Iowa Greenhouse Gas Action Plan.

Iowa has the potential to benefit greatly from energy savings and from limiting greenhouse gases through the implementation of the priority options. Implementing the priority options identified in this Plan could save the state up to \$300 million annually from reduced energy costs, with an additional environmental savings of \$32 million annually from avoided emissions.

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SUMMARY TABLE A
Priority Options and Maximum Feasible Reductions in
Iowa Greenhouse Gas Action Plan ,
in the Year 2010 from 1990 Baseline Year

Sector	Recommended Options to Reduce Greenhouse Gas Emissions in Iowa	Priority* Reduction (CO ₂ reductions million tons/year)	Maximum* Feasible Reduction
Agricultural	1) Reforestation of Marginal Lands (riparian zones, native tree plantings).	2.7	13.5
	2) Production of energy crops (switchgrass and poplars).	0.09	0.26
	3) Reduction of nitrogen fertilizer applications	0.4	0.4
	4) Reclamation of methane gas at large hog lots (over 5,000 head)	0.1	0.7
	5) Continued improvement of farm efficiency	0.1	0.1
Transportation	1) Improve vehicle fleet efficiency (revenue neutral fee/rebate)	2.9	4.1
	2) Discourage single occupancy trips	0.18	0.36
Utility	1) Carbon Dioxide Emissions Inventory	1.4	2.1
	2) Wind Power Development (105 MW by 2000)	0.28	0.56
	3) Demand Side Management (voluntary)	0.2	1.0
	4) Emissions Trading (market based)	2.0	3.5
Commercial/ Industrial	1) State (Iowa Energy Bank, Rebuild Iowa, Total Assessment Audit, Climate Wise) Voluntary Programs	0.08	0.2
	2) Federal Voluntary Programs (in concert with state programs)	2.1	4.2
	3) Emissions Trading (market based)	2.0	3.4
	4) Carbon Dioxide Emissions Inventory	1.4	2.0
Residential	1) State and Federal Voluntary Programs	0.67	1.3
TOTAL		16	37

* The difference between Priority Options and Maximum Feasible Reduction Options is in the extent of implementation. For example, in the Priority Option for Reforestation, 200,000 acres would be replanted; for the Maximum Feasible Option, 1,000,000 acres would be replanted.

The Science of Climate Change

The increase in "greenhouse gases" in the atmosphere has led to concern regarding the potential for global warming and climate change. The effect is analogous to rolling up the windows of your car on a bright summer day. Short wave solar energy can pass the windows striking the interior surfaces of the car. But long-wave radiation cannot escape back through the windows, and the temperature of the car heats up. Greenhouse gases also absorb long-wave radiation, and they are increasing in the atmosphere (Table 1), but it is not certain whether climate has been affected.

The vast majority (~98%) of earth's greenhouse effect is natural, caused by water vapor and carbon dioxide. Without these gases, earth would be so cold as to be uninhabitable, 33°C (59°F) cooler than it is presently. The annual global mean surface temperature of earth is 15°C (59°F), and the global temperature in the absence of natural greenhouse gases would be a frigid -18°C (0°F). The "greenhouse effect" is natural and it is beneficial to life on Earth.

Concern arises because anthropogenic greenhouse gases are increasing including carbon dioxide, methane, chlorofluorocarbons, and nitrous oxide. These greenhouse gases have the potential to change climate if left unabated. Molecules with more than two atoms (like the windows of the car) absorb long-wave radiation, and when they do, the earth's surface warms. The relative effectiveness of each of the gases is not equal. Table 1 shows that methane (CH₄) is 22 times more potent and nitrous oxide is 270 times more potent as a greenhouse gas than carbon dioxide on a molecular basis.

Greenhouse gas concentrations are increasing in the atmosphere due to increases in global population and per capita consumption. Carbon dioxide (CO₂) from fossil fuel emissions is increasing at 0.4-0.5% per year (Figure 1). A little more than half of the anthropogenic (human caused) greenhouse gas effect is due to carbon dioxide (Table 1). Methane (CH₄) concentrations in the atmosphere, another potent greenhouse gas, are increasing at ~0.7% per year, primarily due to flooded rice production and animal husbandry required to feed an expanding population (Figure 2). The *rate of increase* in methane concentrations is beginning to decline, perhaps because leaks at natural gas pipelines have been controlled.

TABLE 1
Summary of Major Anthropogenic Greenhouse Gases

Gas	ppmv Concentration	%Greenhouse Contribution	%/yr Rate of Increase	Half-life yrs	Relative Greenhouse Effect per kg	Relative Greenhouse Effect per mole
CO ₂	360	55-60	0.4-0.5	150	1	1
CH ₄	1.7	15-20	0.7-0.9	7-10	62	22
N ₂ O	0.31	5	0.2	150	270	270

*concentrations are on a volumetric basis (mixing ratios)

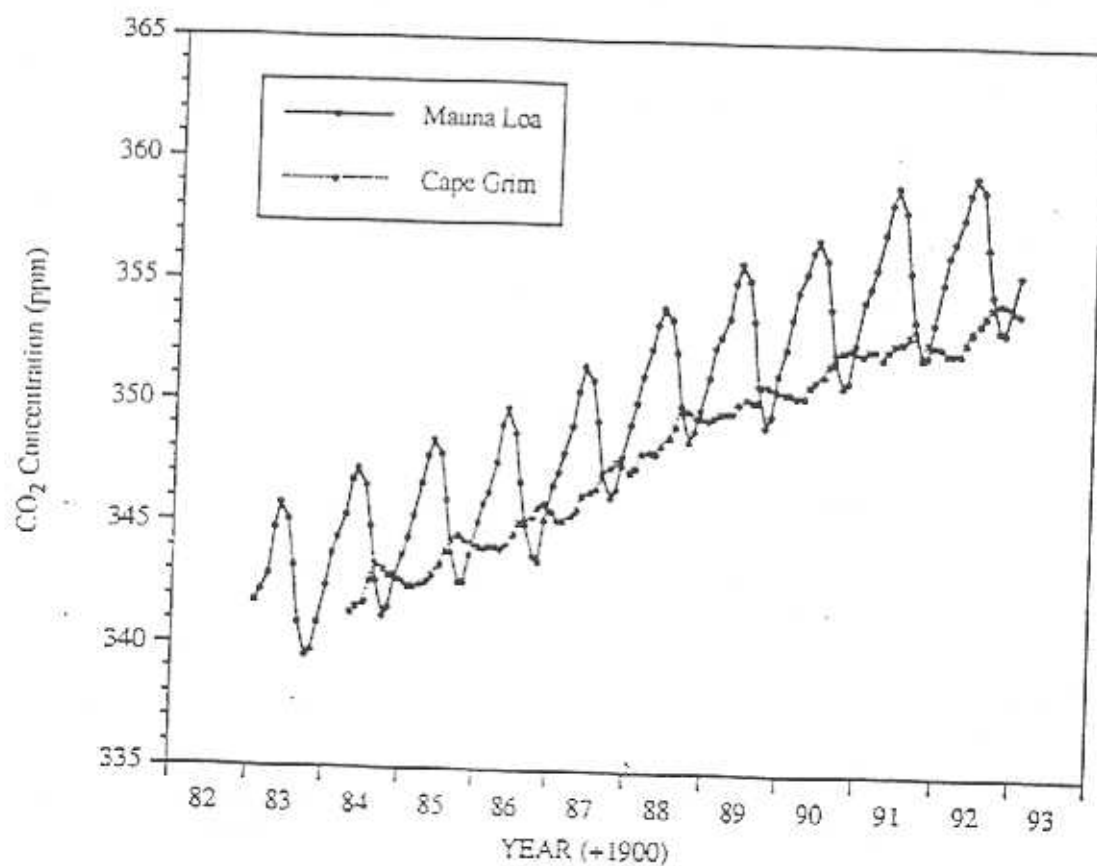


Figure 1. Trend of carbon dioxide concentration at two stations in the northern hemisphere, Mauna Loa, Hawaii, and the southern hemisphere at Cape Grim, showing the exponential increase in CO₂ at 0.5% per year. High amplitude oscillators at Mauna Loa reflect the annual photosynthesis cycle in the northern hemisphere where most of the continents lay.

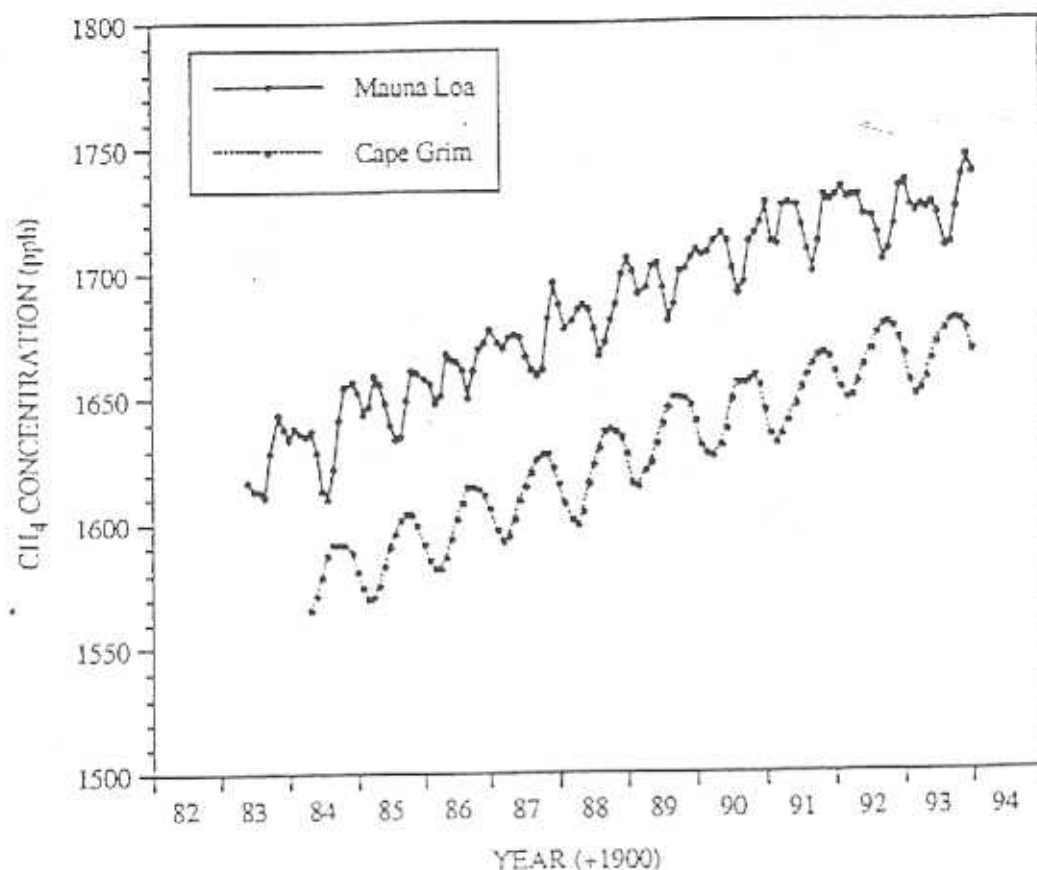


Figure 2. Trend of methane concentrations at two stations in the northern hemisphere, Mauna Loa, Hawaii, and the southern hemisphere at Cape Grim, showing the exponential increase of methane at 0.9% per year (but concentrations appear to be leveling off).

Another greenhouse gas, nitrous oxide (N_2O) is the result of increasing fossil fuel emissions, slash burning of forests, and nitrogen fertilizer applications worldwide. As ammonia-nitrogen is oxidized in the soil and nitrate fertilizer is denitrified, nitrous oxide represents a chemical of intermediate oxidation state which is volatilized to the atmosphere. Figure 3 shows that N_2O is increasing rapidly in the atmosphere and, even though it is only ~5% of the anthropogenic greenhouse gas effect, it will be a difficult gas to control. Fertilizer applications of ammonia, ammonium nitrate, and ammonium sulfate are likely to increase worldwide to feed the expanding world population.

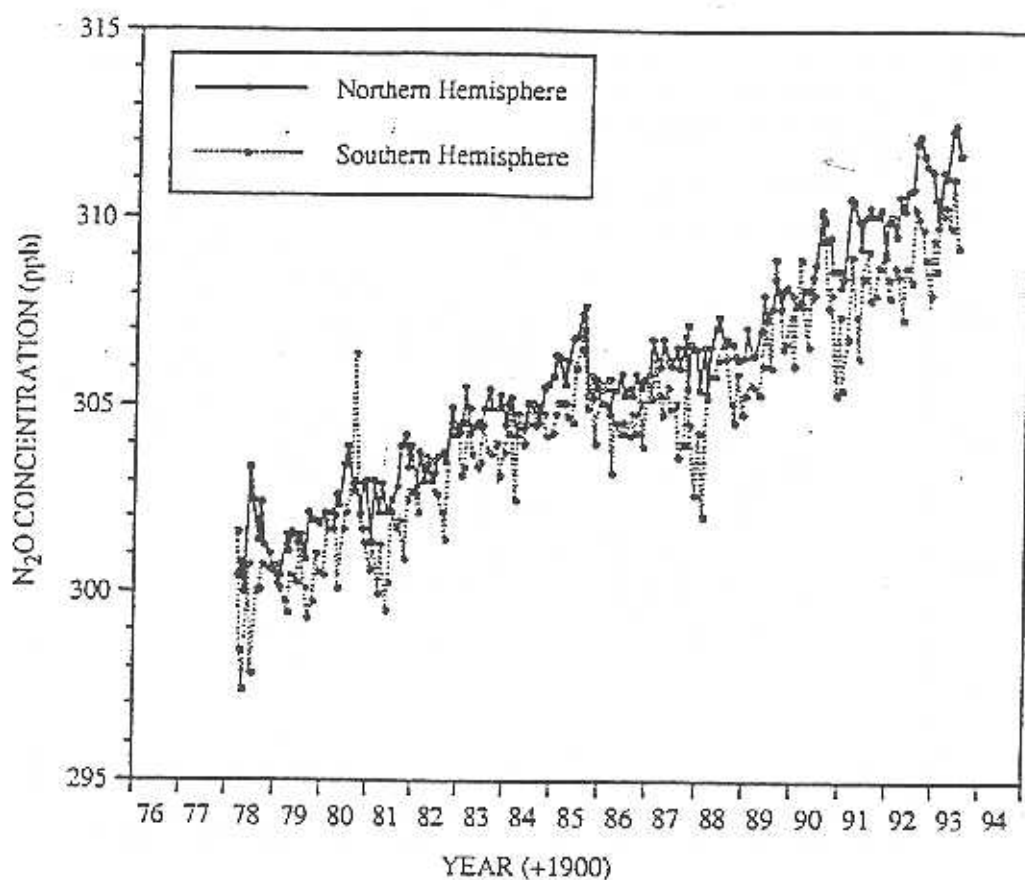


Figure 3. Trend of nitrous oxide concentrations at two stations in the northern and the southern hemisphere, showing the exponential increase of N_2O at 0.25% per year.

Carbon dioxide has increased 27% from 280 ppm in 1765 to 360 ppm in 1995. A total surface energy change of 2.5 watts/m^2 is attributed to anthropogenic greenhouse gases to date. To put the number into perspective, a standard Christmas tree light bulb puts out ~ 4 watts of energy, so if there was one additional light bulb of this kind shining continually on every square meter of earth's surface, it would result in a climate forcing of 4 watts/m^2 . This climate forcing is small relative to the total input of energy from the sun (the solar irradiance or solar constant) of 1372 watts/m^2 . The solar constant is not constant – it varies with sunspot activities and other factors ($\pm 0.1\%$), and it may have increased slightly in recent times. Also, humans have put more sulfur dioxide into the atmosphere (from coal and oil combustion) which results in the formation of sulfate aerosols and brighter clouds (albedo increases) that causes "global cooling". This cooling effect is somewhat less than the calculated warming effect due to greenhouse gases. However, there is considerable uncertainty in all of these effects, and they are estimated by use of global dynamic models, General Circulation Models or GCMs.

The earth is currently in a relatively warm climate period. The global average surface temperature of the earth is -0.6°C (1.1°F) warmer than the earliest period of record, 1860. But this temperature change is still within the interannual variability of temperature ($\pm 0.7^{\circ}\text{C}$) due to large scale circulation patterns (e.g., El Niño Southern Oscillation events) that we do not fully understand. Eight out of nine of the warmest years on record have occurred since 1980 (1980-1995) in a 135-year period. Last year, 1995, was the warmest year on record and 1990 and 1991 were close seconds. 1992 and 1993 were relatively cool because sulfur dioxide and ash particles were blown high into the atmosphere ($> 35,000$ ft) by the eruption of Mt. Pinatubo volcano. All of these observations have been modeled with some success using General Circulation Models (GCMs).

In December, 1995, scientific representatives from 120 nations and the Intergovernmental Panel on Climate Change met to discuss the issues of global change. For the first time, they agreed that while many uncertainties remain, "the balance of evidence ... suggests a discernible human influence in global climate." In July of 1996, the 2nd Conference of the Parties to the Framework Convention on Climate Change met in Geneva with 160 countries attending. They called for enforceable greenhouse gas reductions that go beyond the Climate Treaty goal (stable emissions at 1990 levels by the year 2000) because the weight of the evidence is now substantial, and the consequences of climate change are potentially so grave for earth's people and ecology. On December 9-13, 1996, delegates from 140 countries met again in Geneva to negotiate reduction targets for 2005 and 2010. The delegates could not agree on a protocol, but an agreement must be concluded by the ministerial-level meeting (3rd Conference of the Parties) scheduled for December 1997 in Kyoto, Japan.

The best estimate of warming is $0.8\text{-}3.5^{\circ}\text{C}$ ($1.4\text{-}6.3^{\circ}\text{F}$) with a most probable estimate of 2.0°C (3.6°F) by the end of the 21st century (Intergovernmental Panel on Climate Change, IPCC, Second Assessment Report, 1996). If carbon dioxide and other greenhouse gases continue to increase, all models predict a warming trend in the 21st century. Precipitation would increase globally, but mid-continental areas, like Iowa, would most likely become warmer and drier. Sea level has been rising already, about 3.9 ± 0.8 mm/year in 1993 and 1994. It would continue to rise by 15-95 cm (0.5-3.0 ft) by the year 2100, enough to cause salinity intrusion into the drinking water supply of coastal cities and inundation of coastal properties. A significant fraction of Florida and small island countries could be under water by the end of the next century. One of the greatest economic costs of global warming is expected to be health related, including the increase in malaria and schistosomiasis and problems of extreme heat affecting the elderly. Although an expected temperature increase of 3.6°F may not seem like much warming, it could affect the extremes of weather considerably, resulting in stronger, more frequent hurricanes, droughts, floods, and costs to society. One of the biggest proponents of further controls on carbon dioxide emissions is the insurance industry, which has been monitoring the Framework Convention on Climate Change closely. They are worried that escalating claims in recent years due to storms will leave them bankrupt.

Under a warmer, drier climate, Iowa's agriculture would need to adapt rapidly with new hybrids or different crops (wheat, for example). Energy and air-conditioning costs would increase, and the ecology of plants and animals would change dramatically. One of the greatest economic effects on Iowa of a drier, warmer climate would be health related. The number of days greater than 100°F would increase significantly, resulting in heat stress and possible death to sensitive, elderly citizens. Iowa has the second oldest population in the United States and the greatest percentage of citizens over 85 years of age.

1990 Iowa Greenhouse Gas Emissions and Baseline Forecast

Following is the historical data and baseline forecast for energy and carbon dioxide emissions in Iowa, 1960-2010, in Figure 4. Non-energy sources of greenhouse gas emissions are a much smaller portion of total emissions and are presented individually throughout this Action Plan.

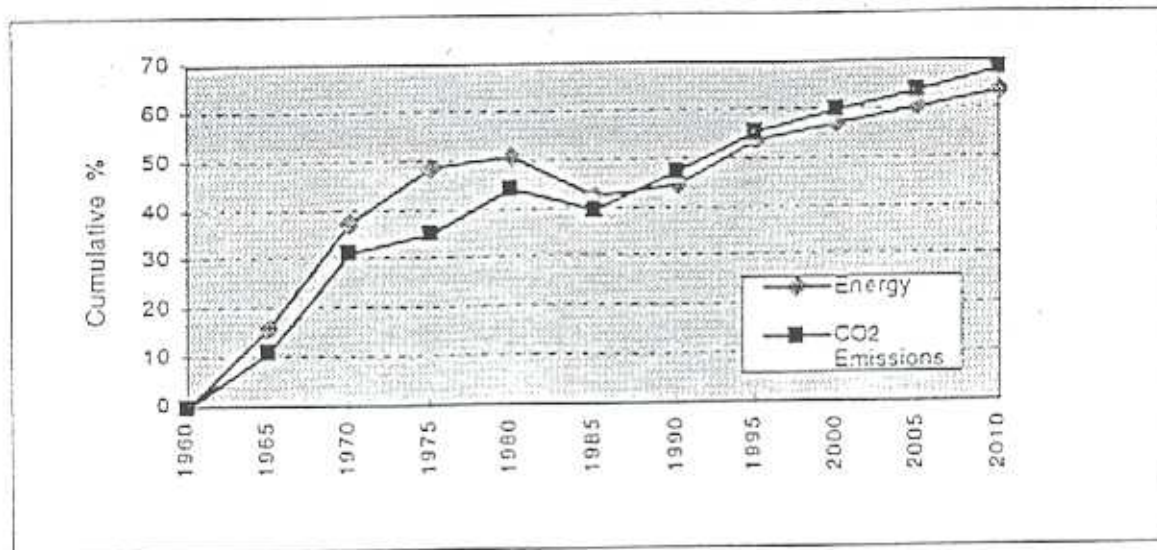


Figure 4. Iowa Cumulative Growth Rates, Energy vs. CO₂ Emissions (from Energy).

The Energy Bureau of the Iowa Department of Natural Resources has forecast energy consumption through the year 2010 using U.S. Department of Energy, Energy Information Administration forecasting techniques and trends. The projection assumes continued moderate economic growth such as Iowa has experienced in recent years. Projections begin from year 1993 and show increasing total energy consumption, on a Btu-basis, at roughly 0.65 percent annually. Figure 5 shows the forecast through the year 2010, with total energy consumption equaling 1011 trillion Btu per year (tBtu/yr) in 2000, and 1082 tBtu/yr in 2010.

Emissions of Carbon Dioxide (CO₂) are forecast to increase at a slightly faster rate than total energy consumption (Figure 6). This is due to a predicted future reliance upon coal-fired electricity generation, illustrated by faster increases in coal consumption as compared to natural gas or petroleum fuels. Coal is forecast to provide 47 percent of total energy needs in 2000 and 48 percent in 2010. Natural gas is predicted to provide 18 percent of energy needs in both 2000 and 2010, and petroleum products are forecast to provide 34 percent of energy needs in 2000 and 2010. Carbon dioxide emissions from energy consumption are forecast to be 12.5

percent higher in 2000 than 1990 emissions, and year 2010 emissions are predicted to be 22.4 percent higher than 1990 emissions.

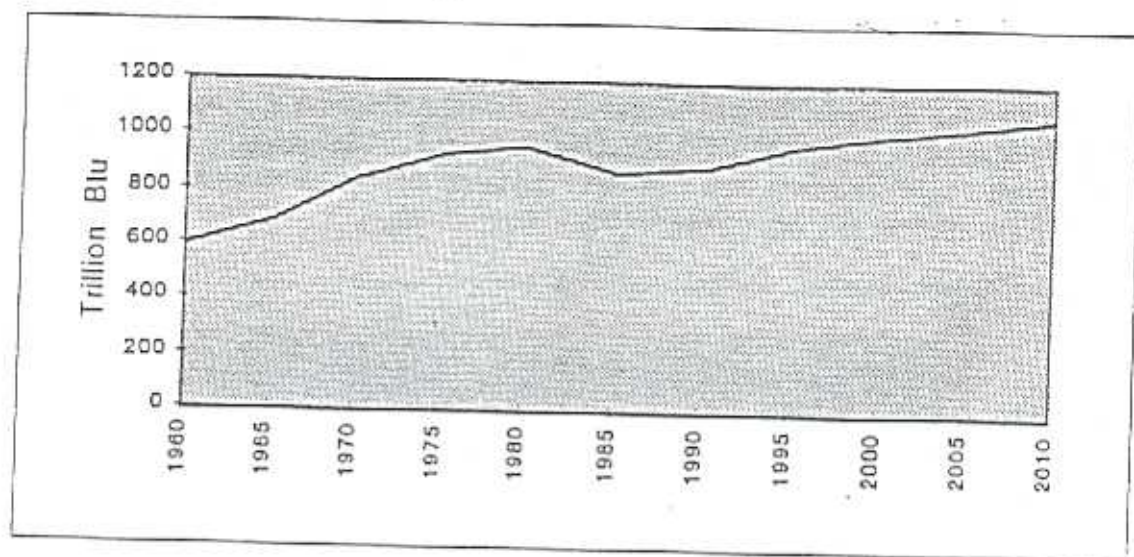


Figure 5. Historical and Projected Iowa Energy Consumption (Trillion Btu).

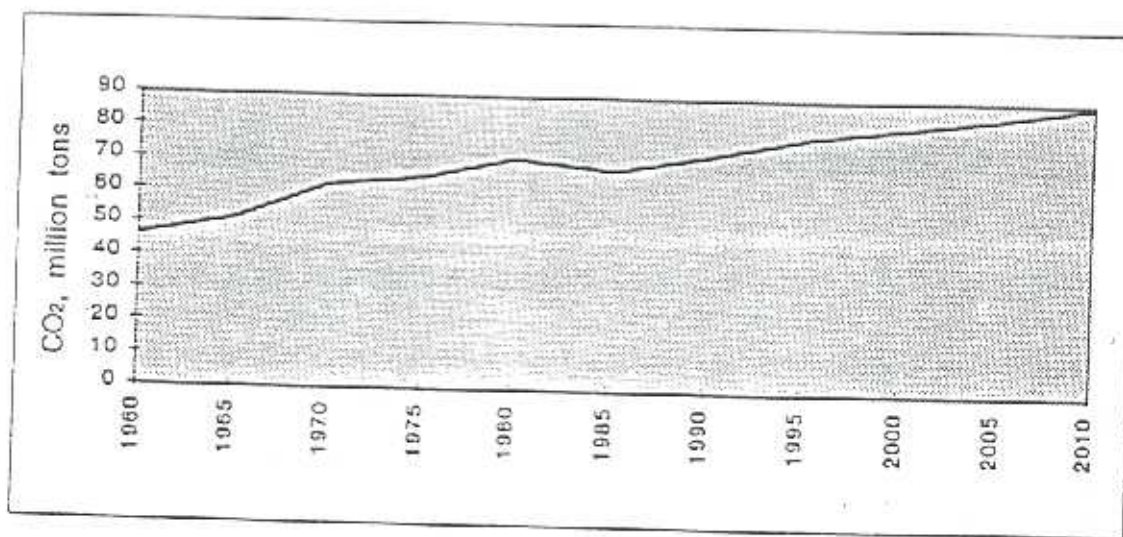


Figure 6. Historical and Projected Iowa CO₂ Emissions from Energy Use (million short tons).

Projections By Sector

Industrial Sector

The industrial sector is forecast to grow steadily through the year 2010, reflecting the current experience of industrial expansion in the state and the overall strength of the U.S. economy (Figure 7). For the period 1990 through 2010, the industrial sector is predicted to be the fastest growing of Iowa's economic sectors. Growth rates are presumed to remain steady at approximately 1.2 percent per year through 2010. Even at that seemingly small growth rate, energy consumption of 326.9 trillion Btu in 1990 becomes 428.7 trillion Btu in 2010, making the industrial sector the largest energy consuming sector of the Iowa economy.

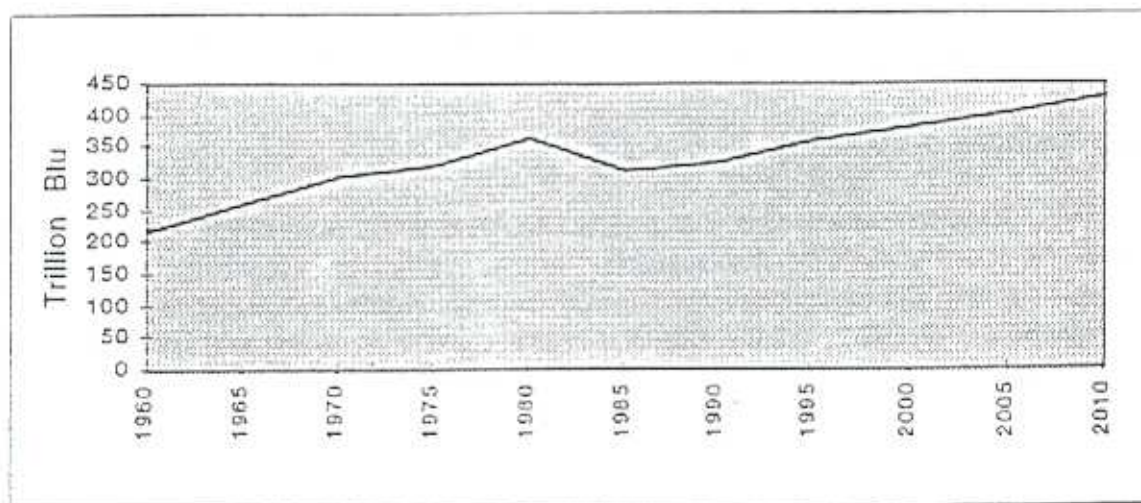


Figure 7. Iowa Industrial Energy Consumption Baseline Forecast (Trillion Btu).

Electric Utilities

Electric generation is predicted to grow rapidly in the future (second-fastest growing sector) (Figure 8). Energy consumption for electric generation is predicted to increase by 21.2 percent from 1990 through the year 2010. While this seems by itself to be a staggering growth rate, it pales in comparison to the consumption increase of 153 percent seen from 1970 to 1990, or the 38 percent increase seen for the decade of 1980-1990. Thus, the forecast seems reasonably conservative, yet does not present a picture consistent with greenhouse gas reduction goals.

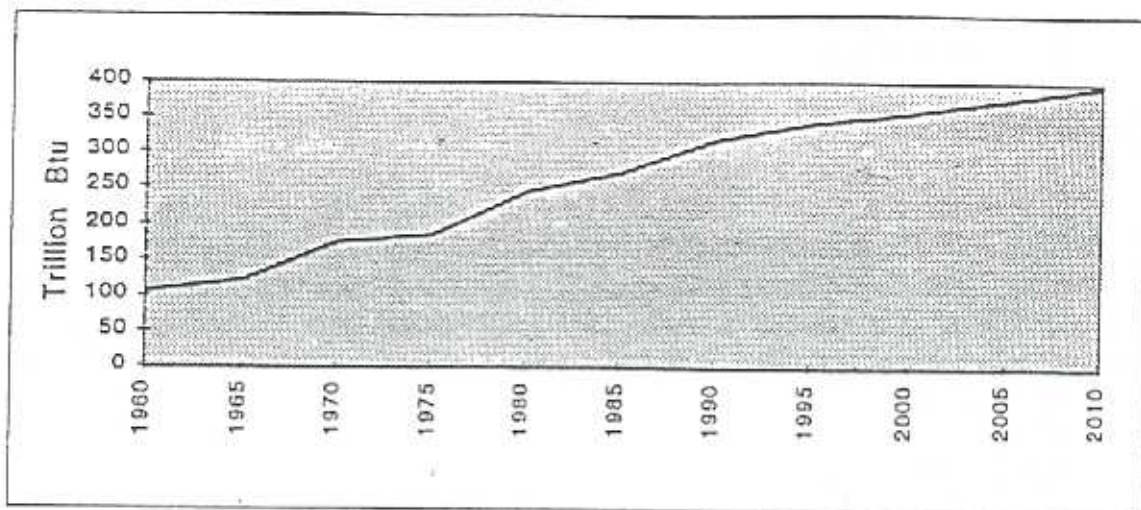


Figure 8. Iowa Electric Utility Energy Consumption Baseline Forecast (Trillion Btu).

Transportation Sector

The transportation sector is predicted to be the third fastest-growing sector of the Iowa economy, behind the industrial and electric utility sectors (Figure 9). Growth of energy consumption of slightly over 21 percent is forecast for transportation. Primary growth comes from growth in vehicle miles traveled and no forecasted increases in vehicle fuel efficiency. However, introduction of more stringent federal fuel efficiency standards would significantly reduce the upward trend in transportation energy consumption.

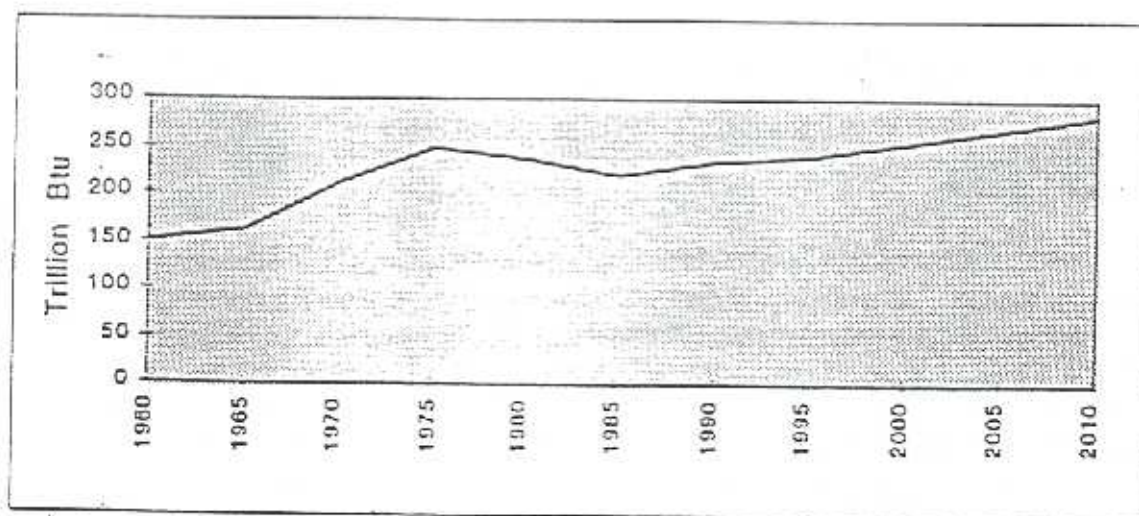


Figure 9. Iowa Transportation Energy Consumption Baseline Forecast (Trillion Btu).

Residential Sector

A decrease in energy consumption is forecast for the residential sector beyond the year 1995, reflecting slow expansion of the Iowa population, renewal of Iowa housing stock, and the resulting energy efficiency increases (Figure 10). Energy consumption for the residential sector of 202.9 trillion Btu is forecast to increase to 220.3 trillion Btu by 1995 but then decrease through 2010, resulting in consumption of 213.8 trillion Btu.

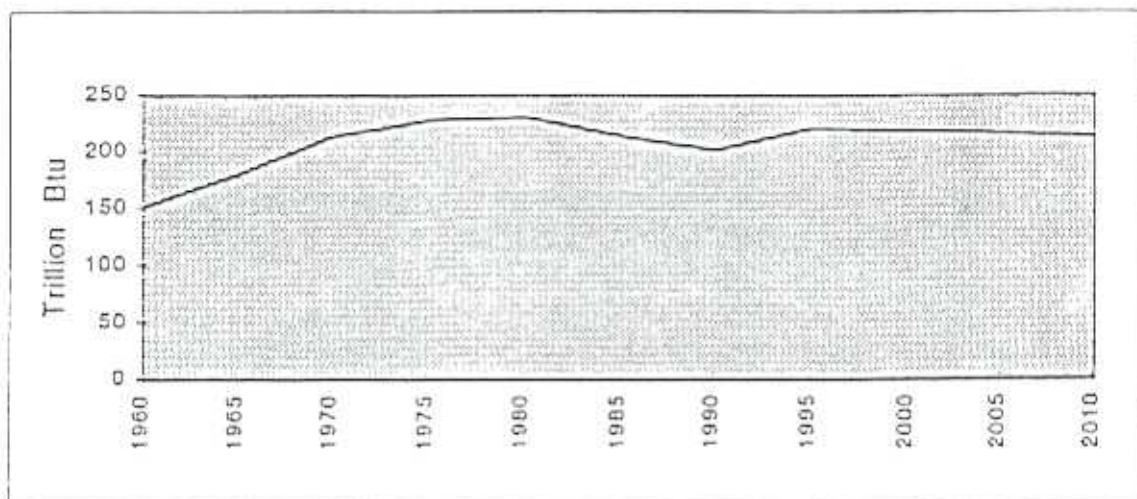


Figure 10. Iowa Residential Energy Consumption Baseline Forecast (Trillion Btu).

Commercial Sector

Energy consumption is a mixed forecast for the commercial sector which includes many farms as well as small to moderate size businesses (Figure 11). (Some farms are classified across commercial and industrial sectors). Energy consumption is assumed to increase by 17.2 percent over the years 1990 to 2000, followed by a slow but steady decrease, reflective of increased energy efficiency in the sector.

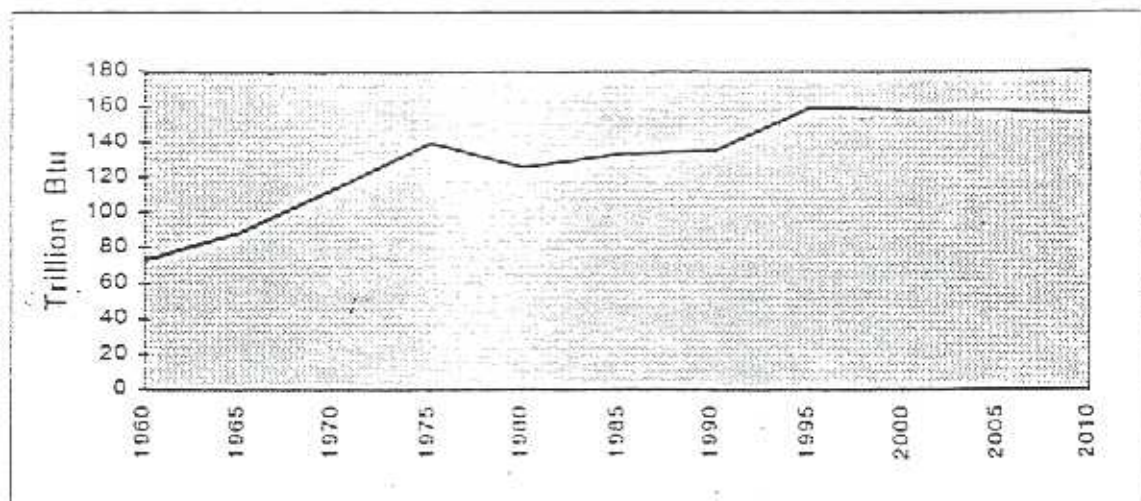


Figure 11. Iowa Commercial Energy Consumption Baseline Forecast (Trillion Btu).

Goals and Targets

In October of 1993, President Clinton and Vice President Gore published The Climate Change Action Plan which stated a goal of reducing greenhouse gas emissions to 1990 levels by the year 2000. The Clinton-Gore plan is consistent with the goals of the Climate Convention, an international treaty that the U.S. signed at the Rio Earth Summit in 1992. The Iowa Greenhouse Gas Action Plan lays the groundwork for Iowa to achieve this goal as a state. While reduction of greenhouse gas emissions is a difficult task, this plan lists several policy options that can make a positive impact on Iowa's economy and environment.

To further the study of greenhouse gas emissions emanating from the states, the USEPA has developed a program, the Global Climate Change Outreach Program, which provides funds for conducting a three-Phase approach to reducing or mitigating greenhouse gas emissions. Phase I funds were for development of a standardized baseline inventory. Phase II funds are for the development of a state action plan for greenhouse gas emission reduction, and Phase III funds are for testing and evaluation of the methodologies developed in Phase II. This report represents Phase II of the program and was developed using the Second Edition of the "State Workbook: Methodologies for Estimating Greenhouse Gas Emissions", and a variety of resources from the Iowa Department of Natural Resources and the U.S. Department of Energy (Energy Information Administration).

Why do anything? The U.S. Climate Change Plan is purely voluntary. However, the reasons for acting now are significant. It is much easier and cost-effective to enact preventive measures now than in the middle of the 21st century when global warming has already occurred, and society is at a much higher level of nonrenewable energy utilization with fewer options to reverse the trend. The Iowa Greenhouse Gas Action Plan can be viewed as an insurance policy; it is an investment against environmental consequences in the future. It will take an unprecedented international effort to curb the increase of greenhouse gases in the atmosphere because emissions are so great and so many regions are underdeveloped and will need to expand their economies. The carbon dioxide environmental signal is very strong, and concentrations will continue to increase in the atmosphere throughout the 21st century.

This Iowa Greenhouse Gas Action Plan is also a plan to strengthen Iowa's economy by diversifying agriculture, raising new energy crops, increasing sales of energy efficient appliances, generation of renewable fuels, and increased competitiveness in manufacturing. It will increase jobs, diversify our economy, and improve Iowa's landscape.

The most significant contribution to Iowa greenhouse gas emissions is made by combustion of fossil fuels for energy. The majority of these fuels are purchased

from outside the state, \$5 billion dollars expended per year. (To put the number in perspective, the State budget is approximately \$4 billion dollars annually.) Reduction in reliance on imported fuels can reduce emissions and also provide a boost to the state's economy. Individual institutions will also benefit by saving on energy expenditures through improving energy efficiency, thus reducing greenhouse gas emissions. Energy efficiency remains the single most cost-effective means to reduce energy costs and greenhouse emissions.

A key to reaching constant emissions by the year 2000, is the speed at which policy options can be implemented. Implementation will set Iowa on a course of reducing emissions far into the future.

The target of Iowa's Greenhouse Gas Action Plan remains the goal of reducing year 2000 emissions to 1990 levels. Greenhouse gas emissions forecasts are employed to estimate emission levels if no action is taken to reduce emissions. This forecast indicates that 93.011 million short tons of CO₂-equivalent greenhouse gas emissions would occur in the year 2000 in the baseline case. Thus reduction of 6.266 million short tons of CO₂-equivalent emissions (7.2% of Iowa's baseline total in the year 2000) are needed in order to meet the 1990 levels of 86.745 million short tons (Appendix A, Table A1).

Iowa is the 15th largest emitter of greenhouse gases (expressed as carbon dioxide equivalents) in the nation on a per capita basis (see Appendix B). Every Iowan emits an average of 29 tons of carbon dioxide per capita per year (Ney and Schnoor, 1995). In October of 1993, President Clinton and Vice President Gore announced a largely voluntary greenhouse gas action plan in which the goal is to limit the emission of greenhouse gases to 1990 levels by the year 2000. However, projections indicate that the U.S. will fall short of its goal in the year 2000.

Carbon dioxide, mostly from fossil fuel combustion, is not the only anthropogenic greenhouse gas of concern, but it is the largest one in Iowa. Table 2 shows the four most important gases and their relative contributions to the greenhouse effect. Chlorofluorocarbons (CFCs) are the freon chemicals used in refrigeration, automobile air conditioners, microelectronics cleaning, and blowing agents. They are slated for curtailment in 1996 under the Montreal Protocol and its amendments, and they are not considered as a part of the Clinton Action Plan. Methane emissions (CH₄) emanate from flooded agriculture (especially rice), ruminant animals (cattle and sheep), and manure management. Nitrogen oxides (NO_x) are from automobile emissions and fossil fuel combustion, and nitrous oxide (N₂O) comes from denitrification of nitrogen fertilizers used on Iowa cropland.

TABLE 2
Net Contributions to Greenhouse Effect in Iowa, 1990 Baseline Year

Greenhouse Gas Emissions	% Effect
Carbon Dioxide, CO ₂	76.8%
Methane, CH ₄	17.9%
Nitrous Oxide, N ₂ O	5.4%

Table 3 is a breakdown of various source contributions to CO₂ emissions in Iowa. Most of the emissions are due to combustion of coal. Eighty-three percent of the state's electricity is generated by coal-fired plants, so electric utilities are an important sector of the economy in this regard.

TABLE 3
Energy Source Contributions to CO₂ Emissions in Iowa,
1990 Baseline Year

Coal	55%
Petroleum	28%
Natural gas	16%
Ethanol	~1%

Energy efficiency is the best method for curbing greenhouse gas emissions. Often, energy efficiency measures can be implemented with no negative impact on one's budget, as the costs of improvements can be paid through lower utility bills. To examine energy efficiency, the Action Plan will present potential savings in the agriculture, transportation, utility and industrial, commercial, and residential sectors, and particularly in areas where CO₂ emission reduction potential is the greatest.

Table 4 shows that the industrial sector is the largest contributor to Iowa greenhouse gas emissions followed by the transportation, residential, and commercial sectors. It is possible to make policy decisions that improve each of these sectors, while also considering the costs and benefits of the proposed action. Not shown in Table 4 is the greenhouse gas emissions for generation of electricity by the utility industry. This amounts to 40.5% of the total CO₂ emissions, which is spread throughout the commercial, industrial, and residential sectors.

Renewable energy crops such as switchgrass can be utilized to replace fossil fuel emissions. Reforestation is another method that can curb greenhouse gas

emissions. Perennial biomass (trees especially) have a great advantage over row-crop annual agriculture because they do not disturb the soil to the same extent (decreasing soil respiration and release of CO₂) and because trees sequester CO₂ and accumulate a large amount of woody biomass. This biomass can either be allowed to accumulate (native trees can store CO₂ and decrease Iowa net emissions) or energy crops can be harvested on a planned 6-year rotation and used to replace nonrenewable fossil fuels. Pelletized or gasified fuel wood could be an effective replacement for propane in corn-drying operations, for heating of residential homes, or for heating of confined feeding operations in Iowa agriculture. Co-firing of coal-burning power plants with switchgrass or poplars can save emissions by replacing coal utilization.

TABLE 4
1990 Baseline Greenhouse Gas Emissions by Sector
(% as CO₂-equivalents)

Economic Sector	% Emissions
Industrial	37.4
Transportation	25.2
Residential	22.2
Commercial	15.2
TOTAL	100.0

Criteria used to evaluate each element of this action plan include the cost and feasibility of accomplishing the task under current market and social conditions. Much of this analysis is qualitative, because determination of precise cost and benefit measures are difficult, if not impossible, to determine. However, by following the course of action recommended in this plan, Iowa could save 6.3 million short tons of CO₂-equivalent emissions in the year 2000, or 7.2% below the baseline for 2000. Emission reductions would continue into the twenty-first century.

Policy Options

The policy options presented under the Action Plan are intended to reduce net Iowa greenhouse gas emissions. Options are presented from all sectors of the Iowa economy, with particular attention given to the agricultural and industrial/utility sectors as high impact sectors that can be influenced at the state level. The transportation sector can be influenced primarily at the federal level.

Also analyzed are impact estimates from the Clinton-Gore action plan for federal programs that Iowa could not implement on its own, but which may be worthy of attention from the state. Other options are simply listed to indicate support for the federal actions.

Lastly, alternative options are presented which the project team did not feel were viable options at this time, but they may be needed in the future. Their potential for emission reductions is discussed in gross terms and reasons are provided for their difficulty of implementation.

Recommended policy options in this action plan include two types:

- Priority Options and
- Maximum Feasible Reduction Options

Priority options are defined as those which are practical, efficient proposals that the State should adopt as a part of this plan. They are necessary to reach the Climate Convention objective of curtailing emissions to 1990 levels by the year 2000 or soon thereafter. Maximum feasible reductions include the priority options plus other additional policies that would be more difficult to achieve in Iowa for economic, political, or social reasons. They are not easy to implement, but they are effective and technically feasible.

Agriculture

Agriculture is a critically important economic activity in Iowa that is included in the industrial and commercial sectors of this Greenhouse Gas Action Plan. It is also a significant source of greenhouse gas emissions for the State of Iowa. Activities include propane use for drying corn (carbon dioxide emissions), diesel and gasoline use for driving tractors and vehicles, fertilizer use with emissions of nitrous oxide (N_2O), and manure management that releases methane (CH_4) to the atmosphere. Agricultural crops are also used to produce alternate fuels in the transportation sector. For example, soybeans have successfully been used to synthesize soy diesel, and other farm crops have been blended in various formulations that burn well in diesel engines with little or no modifications and less pollution. Cost is the primary problem with bringing biodiesel into the market as an alternative fuel. Likewise, corn has been used successfully in the Midwest to develop ethanol as a partial substitute for gasoline. A subsidy is required to make it competitive at the current time.

Ethanol from Corn

Burning ethanol in blends with gasoline from 5%-85% (10% by volume is most common) has a slight advantage over gasoline and diesel fuel from a greenhouse gas emissions standpoint. Emission factors in units of tons CO_2 per million BTU (tons CO_2 /MMBTU) are given below from the U.S. EPA (1995) State Workbook.

- Ethanol 0.0760 tons CO_2 /MMBTU
- Gasoline 0.0777
- Diesel 0.0799

Renewable ethanol burns "cleaner" than gasoline and diesel (less CO_2 , CO, and hydrocarbons emitted). The controversy lies in estimates of the amount of nonrenewable fossil fuels that must be combusted to produce a gallon of clean-burning ethanol. Most recent articles estimate energy requirements to be in the range of 50 to 100% of the energy equivalent in ethanol. Obviously, if 100% of the energy contained in ethanol is required to produce it using nonrenewable fossil fuels, then there is no greenhouse benefit. However, if only 75% of the energy in a gallon of ethanol is required to produce it, then a large benefit accrues in diminished CO_2 emissions because a renewable corn crop has been utilized, which sequestered CO_2 from the atmosphere during the growing season.

Corn ethanol production creates 24 percent more energy than it uses, according to a study performed by the U.S. Department of Agriculture ("Estimating the Net Energy Value of Corn-Ethanol," USDA). Furthermore, the study found, ethanol can replace petroleum imports by a factor of 7 to 1 because it uses abundant domestic feedstocks such as natural gas and propane. While the market price for a barrel of oil is about \$20, the U.S. General Accounting Office estimates its true cost is really

about \$126 per barrel ("Fuels for America", November 1, 1993). When calculating the real cost of gasoline, ethanol becomes even more attractive.

There are many other issues surrounding the use of ethanol from corn that go beyond the scope of this Action Plan including: the use of methyl-tertiary-butyl ether (MTBE) rather than ethyl-tertiary-butyl ether (ETBE) in reformulated gasoline, price subsidies required for ethanol and ETBE from corn, disputed air quality benefits of smog and ozone formation, ethanol trade barriers with Brazil, strategic reliance on foreign oil, balance of payments, the cost of maintaining a military presence in the Middle East to protect oil supplies, energy self-sufficiency, and soil erosion as a result of a renewable crop such as corn.

The biggest problem facing increased reliance on ethanol from corn at the present time is the recent price of corn at near record levels, more than \$3 per bushel, and the politics of maintaining federal and state subsidies to make it cost competitive. There is a potential for ethanol to increase as a result of the 1990 Clean Air Act Amendments as ethanol is used in areas trying to meet mandated ambient air quality standards for ozone. For the purposes of this Action Plan, it is assumed that ethanol production and utilization in motor vehicles will remain roughly constant at 400 million gallons per year. This produces a savings of \$98 million dollars in oil and gasoline purchases within the State of Iowa, and it has created about 12,000 jobs in the ethanol industry (IDNR, 1994 a and b).

Nitrogen Fertilizer Application Reductions

Nitrous oxide (N_2O) has a carbon dioxide equivalent of 270 times a CO_2 molecule. Therefore, reductions of N_2O emissions become significant for agriculture. A number of programs have been in effect in Iowa since 1982 to improve nitrogen management on Iowa farms. The programs included the Big Spring Basin Demonstration Project, the Integrated Farm Management Demonstration Project, the Integrated Crop Management Project, and the Model Farms Demonstration Project. These projects were initially conceived in response to nitrate contamination problems in groundwater and included the goal of producing a soil nitrogen test which would enable farmers to apply only required amounts of nitrogen fertilizers. The education programs were funded by oil-overcharge revenues at a cost of \$26 million, with savings of \$363 million.

The Big Spring Basin Demonstration Project showed basin-wide decreases of over one million tons of nitrogen applied per year (on approximately 200 farms), saving about \$200,000 per year for the farmers involved. The Integrated Farm Management/Integrated Crop Management project demonstrated savings of over 240,000 pounds of nitrogen in 1989 - with no reduction in yields. More impressive, the impact beyond the test areas purely through education has been significant. Iowa farmers have reduced nitrogen application rates, while use in other corn-belt states have shown an upward trend (Figure 12).

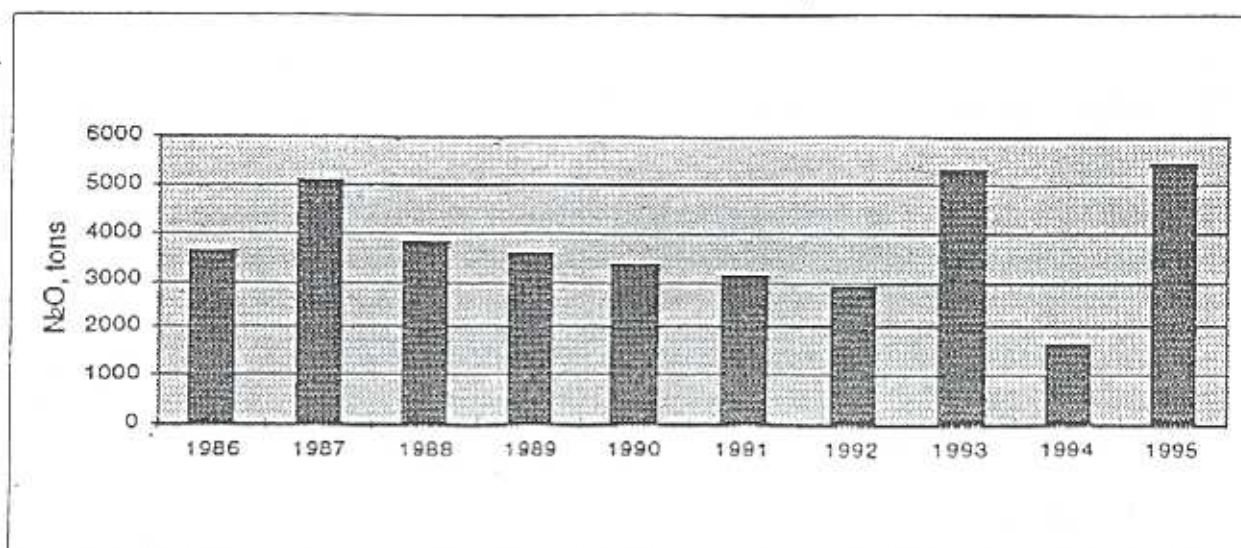


Figure 12. Iowa Nitrous Oxide Reductions Attributed to Decreases in Nitrogen Fertilizer Application Rates (tons N₂O).

Total nitrogen fertilizer reductions of 2.062 million tons from 1985-1995 resulted in savings of \$363 million (Table 5). Nitrous oxide emission reductions during this period were estimated as 37,908 tons, or 10.2 million tons of CO₂ equivalent. Further emission reductions are assumed to be negligible through the year 2000 due to changes in the Federal Farm Bill and current scarcity of corn inventories. In 1995, there were approximately 2 million acres in the Conservation Reserve Program, and a significant fraction of that acreage may come back into production. Increases in corn acreage planted, and the inclusion of marginal lands will likely act together to offset further potential reductions. From 2000 to 2010 a one percent per year savings has been assumed in nitrogen fertilizer application by continuing extension education and programs by the Leopold Center for Sustainable Agriculture that are now in place (Figure 13).

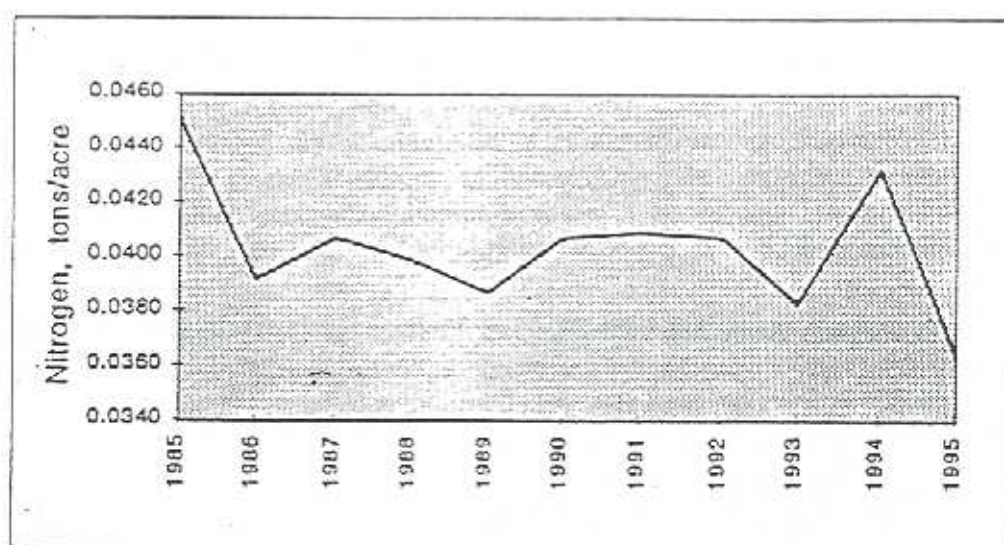


Figure 13. Trends in Nitrogen Fertilizer Application (tons N/Acre).

TABLE 5

Total Fertilizer Used in Iowa, 1985-1994;

averaged rate of fertilizer-N (FN) per acre: the reduction, or difference from 1985 use, and the dollar and energy of the reduction.

(Source: Hallberg, G.R., personal correspondence, 1996)

Year	Total Crop Acres Harvested 1000 acres	Total com Acres 1000 acres	Total N Fertilizer Used as tons N	Reduction from 1985 FN Use tons N	Reduction* from 1985 N ₂ O Emissions tons N ₂ O	Value of Reduction from 1985 FN use dollars	Average FN used per crop acre lbs-N/acre	Reduction in FN used relative to 1985 FN rate 1000-lbs-N	Value of reduction from 1985 FN rate dollars	Energy value of FN reduction in equivalent gallons of diesel fuel gal/dsl-eq
1985	25,030	13,900	1,128,497				90			
1986	23,796	12,300	933,510	194,987	3,585	\$ 58,496,100	78	285,552	\$ 42,832,800	71,388,000
1987	20,956	10,300	852,534	275,963	5,074	\$ 82,788,900	81	188,604	\$ 28,290,600	47,151,000
1988	23,092	11,300	920,833	207,664	3,818	\$ 62,299,200	80	230,920	\$ 34,638,000	57,730,000
1989	24,097	12,600	933,631	194,866	3,583	\$ 58,459,800	77	313,260	\$ 46,989,150	78,315,250
1990	23,276	12,800	247,416	181,081	3,329	\$ 54,324,300	81	209,484	\$ 31,422,600	52,371,000
1991	23,376	12,400	956,888	171,609	3,155	\$ 51,482,700	82	187,008	\$ 28,051,200	46,752,000
1992	23,816	13,200	968,805	159,692	2,936	\$ 47,907,600	80	238,160	\$ 35,724,000	59,540,000
1993	21,916	12,000	840,143	288,354	5,302	\$ 86,506,200	77	284,908	\$ 42,736,200	71,227,000
1994	23,967	13,000	1,035,910	92,587	1,702	\$ 27,776,100	86	95,868	\$ 14,380,200	23,967,000
1995	22,872	11,700	833,477	295,020	5,424	\$ 88,506,000	73	388,825	\$ 58,323,600	97,206,000
TOTAL					37,908	\$ 618,546,900		2,422,589	\$ 363,388,350	605,647,250

Adapted from "A Progress Review of Iowa's Agricultural-Energy Environmental Initiatives: Nitrogen Management in Iowa" (1994 update), G.R. Hallberg et al. Land areas from Iowa Agricultural Statistics and National Agricultural Statistics Service.

Total fertilizer-N tonnage from Bery and Hargett, 1991, TVA; Fertilizer Summary Data, 1990; and Iowa Dept. Agric. and Land Stewardship, Distribution of Fertilizer Reports.

Value of fertilizer calculated at \$0.15/pound N.

Average FN used per crop area, calculated from: total FN used in lbs./total crop (harvested) acres.

Reduction in FN used relative to 1985 FN rate, calculated from: (total crop acres* 1985 FN rate [90 lbs-N/acre] - total crop acres*actual FN rate for year).

Energy Value estimated at 4 lbs-FN = 1 gal diesel fuel (as equivalent btus).

* Emission factor from States' Workbook - N₂O emitted = 0.0117(N) * 44/28

Table 6 shows that corn yields have been unaffected by decreases in nitrogen application rates in Iowa, and this is the message that must be conveyed to farmers. Corn yields have been primarily affected by weather patterns. 1992 and 1994 were favorable years with timely rainfall that produced record yields despite approximately 17-19% reductions in N-fertilization rates compared with 1985. 1988 produced a poor corn yield due to drought, while 1993 produced a poor corn crop due to floods. The corn yield has not been affected by decreased N-fertilization and, thus, the savings reported in dollars, energy, and greenhouse gas emissions are real.

TABLE 6
Corn Yield as a Function of Fertilizer-N Application Rate

	Avg. Iowa Corn Fertilizer-N Rate lb-N/ac	Avg. Iowa Corn Yield bu/ac
1985	145	126
1986	131	135
1987	132	130
1988	139	84
1989	128	118
1990	127	126
1991	120	117
1992	118	147
1993	114	80
1994	121	152
1995	120	123

Manure Management Improvements

On a CO₂-equivalent basis, emissions of methane from animal wastes are a significant contributing factor to greenhouse emissions from Iowa. Given the large number of hogs in the state (currently ~14 million), hog operations are the largest subset contributing to these emissions, providing nearly 87 percent of total animal waste methane emissions.

Iowa has the largest hog production of any state. Currently, it has 14 million hogs, which is about five times greater than the number of people (2.8 million population). The greenhouse gas emissions of a mature hog is approximately equal to 2.5 people. Thus, Iowa with a population of 2.8 million people has a population equivalent of roughly 35 million people in the form of hogs. Manure management from these animals becomes a problem and a major release of greenhouse gas as

methane. Nearly 12% of Iowa's total greenhouse gas emissions were from domesticated animals and manure management (see Table A1).

Given the recent debate over the use of large hog-confinement operations in the state, options are presented for both large scale and small scale operations. For the large scale operations, where wastes are concentrated and maintained in large quantities, anaerobic treatment and capture of the gas would result in large emissions reductions compared to waste stabilization lagoons where methane escapes to the atmosphere. Recapture of the methane for energy recovery, or combustion by simple flaring, would greatly reduce methane emissions. Current regulations already require the recapture of methane emissions from landfills, and the greenhouse gas inventory shows that manure methane emissions nearly equal those from landfills.

For small producers, frequent application of manure to fields reduces the evolution of methane from the waste. The more surface area that can be exposed to the atmosphere, the lower the incidence of the waste undergoing anaerobic decay which is the major methane production mechanism. Manure enhances the quality of the soil and adds organic carbon to the soil profile. Aerobic respiration results in a slow release of carbon dioxide rather than methane which has 22 times more global warming potential on a molecule-per-molecule basis.

Under this Greenhouse Gas Action Plan, large producers (greater than 5000 animals) would be required to have methane capture facilities by the year 2000. State legislation will be required to implement this priority option, and it will save ~ 25,000 tons of CO₂-equivalent emissions per year after the year 2000. Methane capture would be consistent with other environmental goals such as impermeable or concrete holding basins to prevent leaks from earthen lagoons. The authors have assumed a 10% reduction in annual emissions due to methane capture beginning after the year 2000 through 2010.

General Energy Efficiency Trends In Agriculture

A study conducted by Michael Duffy of the Leopold Center for Sustainable Agriculture illustrates the changing energy use on Iowa farms. Total farm energy consumption in 1989 was only 60 percent of 1975 consumption, yet there was little change in acreage farmed. The gain in farming efficiency led to an average annual reduction of 4.38 percent, or 3,056,058 MMBtu. Similarly emissions of greenhouse gases from farm fuel consumption have decreased an average of 3.59 percent annually, representing 234,306 tons of CO₂ saved annually.

For this Greenhouse Gas Action Plan, it is assumed that further efficiency gains will be made in the period between 1990 and the year 2000. To employ conservative savings estimates, the authors have assumed that reductions will average one half of the rate of 1975-1989, allowing for larger decreases during the energy crisis and farm crisis years of the 70s and 80s. Thus reductions of 117,000 tons per year of CO₂

emissions are claimed from the agriculture sector. Since energy use data from the Energy Information Administration does not clearly place agriculture in either the Commercial or Industrial sectors, it was assumed for simplicity that agriculture is within the Commercial sector activity for emission reductions.

Agroecosystems/Energy Crops

Poplar Plantations

Poplar plantations have many environmentally desirable applications, including use as buffer strips to decrease erosion and nitrate in runoff from highly erodible fields, for treatment and removal of toxic materials from landfills and other soil contaminations, and as an excellent sink of atmospheric CO₂. Newly developed hybrid varieties are more disease resistant, live for 30 to 50 years, and grow extremely fast. A poplar tree buffer strip at Amana, established in 1988 by The University of Iowa, has produced 7.5 tons of dry matter per year after the third season.

Hybrid poplars will store carbon in woody biomass up to a 50 year period until primary production is offset by respiration and decay. As a long-term strategy, trees could be used as fuel, co-fired with coal at power plants, grown on a 6-year rotation, thereby renewing the energy crop. The trees coppice (grow back from the cut stump) so there is no need for replanting. Harvesting equipment would be required. Gasified poplar biomass could also be used as heating fuel for hog buildings, home heating or corn drying (reduces propane or LPG consumption).

Switchgrass

Switchgrass, like poplar trees, is capable of rapidly producing large amounts of biomass per land unit, while sequestering CO₂ and providing a potentially valuable biomass crop. Near Centerville, Iowa, a program is underway to determine the feasibility and economics of growing switchgrass in Iowa as a renewable biofuel that would sequester CO₂ emissions. Switchgrass has an advantage over poplar trees because it is planted and harvested with traditional farm equipment. It is easier to harvest, ship, and handle with conventional farm equipment, but it may not be quite as good of fuel as poplar wood. Switchgrass does not grow as fast (3.5 tons of harvestable dry matter per acre per year) as woody perennial trees.

The following text is excerpted from the Project Summary of the Chariton Valley Biomass Power for Rural Development (Cooper, 1995).

Chariton Valley RC & D Inc., a USDA sponsored rural development organization and IES Utilities, a major Iowa energy company, are leading a statewide coalition of public and private interests to merge the state's agricultural potential with long-term energy requirements to develop a locally sustainable source of biomass fuel. The counties of Lucas, Wayne, Appanoose, and Monroe which make up the Chariton Valley RC & D area in southern Iowa, are the target of this major biomass initiative. Ten percent of the total land in the four-county Chariton Valley area is in Conservation Reserve Program (CRP) - 140,000 acres. In 1996 alone, 90,000 acres of these CRP contracts are set to expire. Much of southern Iowa is well suited to the production of forages and trees. Thousands more acres of marginal lands not in CRP contracts, have limited market potential for production and would be available for biomass production

under favorable economic conditions. A Department of Energy sponsored investigation of renewable energy in southern Iowa has centered around the use of switchgrass, a native grass of Iowa, as one of the most promising sustainable sources of biomass fuel.

Farm program changes and the eventual end of the CRP make adding value and establishing markets for perennial forage crops vital for the area. The Chariton Valley project proposes the establishment of biomass power generation capabilities as an alternative for marketing forages. IES Utilities is participating in the project to determine the feasibility of using a dedicated supply of southern Iowa biomass as a fuel source for one of its facilities. The results of the feasibility study indicate that co-firing switchgrass with coal is the most practical, economical way to establish a biomass energy industry in southern Iowa. Relatively low cost modifications at an existing IES Utilities facility would allow a biomass capacity of 35 MW. The facility would use an estimated 30,000 to 40,000 acres (200,000 tons) of biomass annually. Land currently in CRP that is highly erodible is the perfect source for biomass. Benefits to water quality, soil conservation and the local economy are phenomenal. Much of the targeted land area is in the watershed of Rathbun Lake which supplies 13 Iowa and Missouri counties and 21 cities with water, through one of the largest rural water systems in the United States, Rathbun Regional Water Association. Costs are estimated at \$36.17 per ton of dry biomass produced (Table 7).

Chariton Valley RC & D, Inc. proposes to identify a viable biomass project for at least 40,000 acres by 1996, to compliment a long-term strategy for biomass power in Iowa. The Chariton Valley RC & D area has already received authorization from USDA for a 4,000 acre demonstration project supporting the development of energy crops as a post CRP alternative. A major private supporter will be the Iowa Farm Bureau Federation which is committed to recruit farmers for biomass production and to develop a post CRP industry. Also providing technical assistance is the John Deere Ottumwa Works forage research unit.

Forest and Prairie Restoration

Iowa is perhaps the most ecologically altered state in the nation since pre-settlement times. Currently, it has 90 percent of its land in agriculture. Seventy-five percent of its forests have been cleared, and over 99% of its original prairies have vanished. Iowa has precious little public land and park land. It is not possible to "completely restore" prairie ecosystems, but it is possible to replant native trees and prairie grasses.

Replanting native forests on marginal agricultural land will benefit water quality, soil, groundwater, and wildlife habitat, while sequestering carbon dioxide in woody biomass. Approximately 7.5 tons of dry biomass per acre per year would be produced from native species reforestation. If one million acres (2.8%) of Iowa land were reforested by the year 2010, it would eventually result in the sequestration of 13.75 million tons of CO₂ per year, about 17% of Iowa's total 1990 emissions. Poplar trees would provide a similar carbon sequestration rate, but they are a monoculture, most appropriately managed as a renewable energy crop. Both approaches, poplar tree buffer strips and native forest restoration efforts are needed. As a Priority Option, a total of 200,000 acres should be reforested by the year 2015. This

TABLE 7
Estimated 5 Year Production Budget for Switchgrass
Based on 3.5 tons/acre/year (Cooper, 1995)

	Costs per Acre	Annual
<u>Establishment Year (no-till)</u>		
Seed 6 lbs PLS/ac @ \$2.50/lb =	\$ 15.00	
Herbicides w/appl. @ \$40/ac =	30.00	
Drill, tractor, & operator @ \$15/ac =	<u>15.00</u>	
Estimated Cost:	\$ 60.00	\$ 12.00
<u>Maintenance (annual)</u>		
Fertilizer		
60 lbs. N @ \$.23/lb	\$ 13.80	
30 lbs. P ₂ O ₅ @ \$.25/lb	7.50	
90 lbs. K ₂ O @ \$.17/lb	15.30	
Application Cost	<u>8.00</u>	
		\$ 44.60
<u>Harvest</u>		
Large round bales at \$9.00/ton		\$ 31.50
<u>Land Value Return</u>		
\$350/acre		28.00
Pro rated 1st year opportunity		7.00
<u>Transportation</u>		
\$2.00/mi for 20 tons, assume 10 mile average		<u>3.50</u>
TOTAL COST/ACRE		\$ 126.60
Total Cost per ton based on 3.5 ton/acre		\$ 36.17

would be accomplished by voluntary efforts, "free-trees" programs, CRP Program conversion to permanent forest land, and land purchases. If \$5 million per year in revenue were raised over a 20-year period for reforestation, \$100 million dollars would accrue for planting (reforesting) 200,000 acres of land at a cost of \$500 per acre.

Prairies do not sequester much carbon dioxide in comparison to woody biomass because the grasses decompose each year. They do, however, provide wildlife habitat, biodiversity, and soil erosion control -- other valuable environmental

benefits. Prairies also help to restore soil tilth, soil quality, and organic carbon to the deep soil profile. Assuming that 10% of net primary productivity of prairie grasses goes into roots and storage as soil organic carbon, then 0.3 tons dry matter per acre per year would be sequestered and added to the soil organic carbon pool. Some of this organic carbon would be reoxidized by soil microbes, but a portion of it would be stored as soil carbon. For the purposes of this Action Plan, prairie restoration is not a priority option because it does not sequester sufficient carbon dioxide, but it may be a desirable strategy for other environmental benefits.

The most available publicly-held lands in Iowa are 600,000 acres of roadsides. Roadside prairies are increasing for their utility and beauty, although they are "linear habitats" and not ideal prairie examples. Other programs include the Walnut Creek National Wildlife Refuge which has restored about 1,100 acres of natural prairie in Iowa since 1990. Their 20-year goal is to plant 8,600 more acres. The U.S. Fish and Wildlife Service is receiving comment on a plan to restore up to 100,000 acres of prairie on contiguous land with corridors from Des Moines to western Minnesota.

Maximum Feasible Energy Crop Strategy Assessment

In this Action Plan, a maximum feasible reduction (MFR) option is reforestation of approximately 1 million acres of Iowa land by the year 2015. Native trees and hybrid poplars could be planted on marginal lands. Hybrid poplars could be grown in buffer strips for control of nonpoint source runoff or as an energy crop for co-firing with coal at power plants. Native trees could be established as forest land and/or harvested periodically for their hard wood (e.g., walnut and oak). Maximum feasible reduction is defined as those policy options that are effective and technically feasible but would require major funding and/or legislative action.

CO₂ sequestration in Iowa in pre-settlement days accounted for 96 million tons of carbon dioxide by 7 million acres of forest and woodland (savanna). This represents more than the present day CO₂-equivalent emissions in Iowa.

$$(7.5 \text{ tons dry matter/acre-yr}) \times (7 \text{ million acres in Iowa}) \times (0.5 \text{ carbon/dry matter}) \times (44 \text{ CO}_2/12 \text{ C}) = 96 \text{ million tons/yr}$$

Eventually, the woodlands reached a mature climax stage, and they were no longer a net sink for CO₂, but they were renewed by natural fire.

The current situation in Iowa is a land use pattern with 2.1 million acres of forests out of a total 36 million acres (IDNR, 1996). Corn, beans, and pasture account for most of the remaining land use (with urban and wetlands a small fraction). Corn, beans, and pasture also sequester considerable carbon dioxide, but it is rapidly returned to the atmosphere when the plants die and they are consumed following harvest. To sequester carbon dioxide in newly planted forests would require

harvesting and the replanting of new trees, so that the forests were always in a state of net growth.

If Iowa could reforest 200,000 acres of land (priority option) or 1,000,000 acres of land (maximum feasible reduction scenario), it could sequester 2.7 million tons CO₂/yr of 13.5 million tons CO₂/yr, respectively.

$$(7.5 \text{ tons dry matter/acre-yr}) \times (1 \text{ million acres}) \times (0.5 \text{ carbon/dry matter}) \times (44 \text{ CO}_2/12 \text{ C}) = 13.5 \text{ million tons/yr CO}_2$$

The maximum feasible reduction scenario would sequester approximately 16% of our 1990 annual emissions by the year 2015.

The maximum feasible reduction strategy is quite "feasible" if one considers that 2.0 million acres of Iowa's marginal land are currently set-aside in the USDA Conservation Reserve Program (CRP). One could establish a program of incentives to encourage farmers to plant CRP land into woodlands or riparian zone buffer strips for soil and water quality benefits. Some of the revenue generated as a part of implementing this Action Plan will be used for that purpose.

To sequester all of Iowa's greenhouse gas emissions would require about 6 million additional acres (one-sixth of Iowa's land). This is not an impossible task, but it would require a large tract of forest land (greater than that which was present at the time of settlement, pre-1850) to be managed for multiple uses (Table 7). Planting native species, poplar tree buffer strips, and switchgrass as an energy crop are part of a total management strategy in this Action Plan, and the recommended additional area is 200,000 acres by the year 2015 (Priority Option) or 1,000,000 acres as a Maximum Feasible Reduction.

Economics: Some energy crop policy options can save money. Based on experience at The University of Iowa growing hybrid poplar trees, the strategy is already close to breaking even. If markets develop for hybrid poplar in Iowa, such as the pulp and paper market in Wisconsin and Oregon, poplar plantations could actually earn extra income for farmers in addition to sequestering carbon dioxide. Hybrid poplars can produce about 7.5 tons of stem (bole) per acre per year with a heating value of 8400 BTU/lb dry matter (Licht, 1990). The trees would be grown on a six-year rotation, but they coppice (grow back from the cut-stump), so there is no need to replant. The Electric Power Research Institute (EPRI) indicates that the poplars should be worth \$1.96 per million BTU when co-fired with coal. Thus, the net income would be ~\$247/acre, not much lower than that for corn acreages, but this would be on marginal land. If the capital cost of land and trees were \$2781/acre, annualized over a 30 year project lifetime with an 8.0% annual interest rate, the annualized cost would be \$247 per acre, exactly equal to the annual income. If the value of the woody crop increases, or the capital cost decreases, the hybrid poplar tree strategy would produce income for the State of Iowa and farmers. A new commodity crop could be created, and greenhouse gases would be sequestered.

Biomass is still more expensive than coal, and our estimates indicate costs of \$2/MMBTU or almost 5¢/kW-hr. Nevertheless, costs of biomass production are decreasing, and little capital investment is required with co-firing. New coal-fired power plants may cost as much as 4¢/kW-hr. In the meantime, we create a new market for biomass and a new commodity crop for farmers at a time when the Conservation Reserve Program (CRP) is changing. Poplars can be grown on marginal lands in Iowa and produce a small income stream for farmers, with concomitant improvements in water quality.

There are other air quality benefits of using renewable fuels rather than coal. For example, a 20-MW coal-fired power plant in Iowa with 30% thermal efficiency, 10,000 BTU/lb coal, 3.5% S, and 0.5% N, would burn approximately 273 tons of coal per day yielding 7.0 lb SO₂/MMBTU and 0.54 lb NO/MMBTU. Both of these gases would require reduction to meet permits under the 1990 Clean Air Act Amendments. If 5% by mass of the fuel was fired as hybrid poplar trees with a moisture content of 10-20%, we could expect the sulfur emissions to decrease proportionately (by 5%) and the NO_x emissions to decrease 1-2%. These pollutant reductions may not sound very large, but they translate into a significant environmental benefit over time. In 24 hours of test-burning, approximately 13.7 tons of dry biomass would be required which is about one-third acre of 6-yr old trees at a density of 600 trees per acre.

Likewise, switchgrass could be co-fired with coal to produce environmental benefits. IDNR (1994a) estimates that if switchgrass to energy was utilized on 2.8 million acres of Iowa land, 14.3 million tons of CO₂, 0.05 million tons of NO_x, 0.5 million tons of SO₂, and 0.06 million tons of particulates would be avoided annually.

Iowa had almost 7 million acres of forest land in 1850, but it is now about 70% depleted. According to preliminary calculations (Table 8), reforestation of 1 million acres could sequester 16% of Iowa's 1990 carbon dioxide emissions for the next 20-30 years until the trees have matured. These figures are only estimates; but they demonstrate the potential for biomass and energy crops to play a significant role in Iowa's greenhouse gas action plan.

TABLE 8
Iowa's Forested Lands (IDNR, 1996) and Reforestation Options

Year	Forested Acres million
1850	6.8
1954	2.4
1974	1.6
1990	2.1
Reforest MFR 2015**	1.0
Priority Option 2015*	0.2

**One million acres is proposed under maximum feasible reduction scenario. *Two hundred thousand acres by the year 2015 is proposed as a Priority Option in this Action Plan, 10,000 acres per year for 20 years.

Reforestation is already taking hold. Since 1990, about 7,000 acres of trees per year have been planted on rural lands and, in addition, urban tree plantings have increased from 200,000 to 600,000 trees per year (IDNR, 1996). The Priority Option of 200,000 acres of reforestation should be easy to accomplish over the next 20 years. Approximately 500,000 acres were reforested between 1974 and 1990. The Maximum Feasible Reduction Scenario of 1,000,000 acres by the year 2015 would require much greater funding and land availability.

Table 9 is a summary of the Priority Options and Maximum Feasible Reductions chosen for the Agriculture Sector. The policies should be implemented as soon as possible (1997) to achieve the estimated savings in CO₂ emissions shown relative to the baseline year of 1990.

TABLE 9
Agriculture Sector Priority Options and
Maximum Feasible Emissions Reductions
to the Year 2010 from 1990 Baseline Year

	Annual CO ₂ Reductions million tons/yr
<u>Priority Options</u>	
Reforest 200,000 acres by 2015 (native trees, poplars)	2.7
Energy Crops (switchgrass, poplars) 35 MW	0.09
Reduce N-fertilizer 1% per yr (2000-2010)	0.4
Large hog lot capture of methane	0.1
Improved farm energy efficiency	0.1
<u>Maximum Feasible Reductions</u>	
Reforest 1,000,000 acres by 2015	13.5
Energy Crops (switchgrass, poplars) 100 MW	0.26
Reduce N-fertilizer 1% per yr (2000-2010)	0.4
Large hog lot capture of methane	0.7
Improved farm energy efficiency	0.1

Transportation

The broad national policies suggested by the Office of Technology Assessment (OTA) and the strategies outlined in the *Climate Change Action Plan* have varying appeal in Iowa. Based on Iowa's characteristics, the policy options that appear to have most potential for influencing energy use in the short term are for the state to increase fuel taxes; discourage single occupancy vehicle trips; promote transit use; and improve fuel economy and vehicle emissions through tax incentives, regulation, and technology improvements. Reductions of emissions from the worst polluting vehicles would have a significant impact on the reduction of the total emissions from all vehicles.

Increased fuel tax

Using fuel tax rates to influence travel choices has many advantages. Changing the relative cost of driving an automobile would have a number of short-term benefits. It would promote carpooling, deter some trip-making, and encourage transit use where available and practical. Over the longer term, a higher fuel tax would increase an individual's incentive to buy vehicles with better fuel efficiency, and even support the development of land use patterns that rely less on vehicular travel for mobility.

The overall level of travel in Iowa has grown steadily during the last several decades. Figure 14 shows how vehicle-miles of travel (VMT) per person have increased from 1960 to the early 1990s. In 1960, each person in the U.S. and in Iowa traveled about 4,000 miles each year. By 1992, each person was traveling about 8,700 miles per year. Iowans traveled somewhat fewer miles per person than was true nationally from the late 1970s through the early 1990s, but the amount of travel is now about equal.

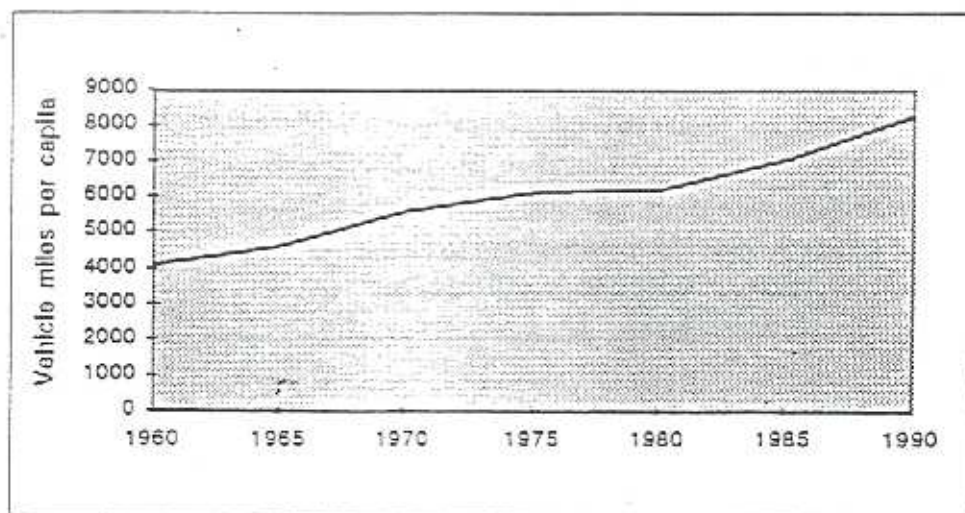


Figure 14. Iowa Per Capita Vehicle Miles Traveled.

Carbon dioxide is emitted via the combustion of gasoline. Approximately 190 lbs. of CO₂ is emitted from the combustion of 10 gallons of gasoline in an automobile. Figure 15 shows how CO₂ emissions from gasoline changed from 1960. In 1977, emissions of CO₂ grew to 160 percent of the 1960 level but fell back to about 130 percent in the early 1990s. The share of all emissions of CO₂ that gasoline is responsible for was about 85 percent in the early 1960s. Since then, this proportion has dropped to about 70 percent, a level reached in 1982 and maintained since then. Emissions per unit of travel have declined significantly over the last twenty years due to advanced vehicle technology. In the 1960s, about 1,200 VMT of travel produced one ton of CO₂. By 1980, it took 1,400 VMT to emit one ton, and by 1992, the amount of VMT needed to produce one ton of CO₂ was almost 2,000. However, the actual number of vehicle miles traveled have also increased significantly.

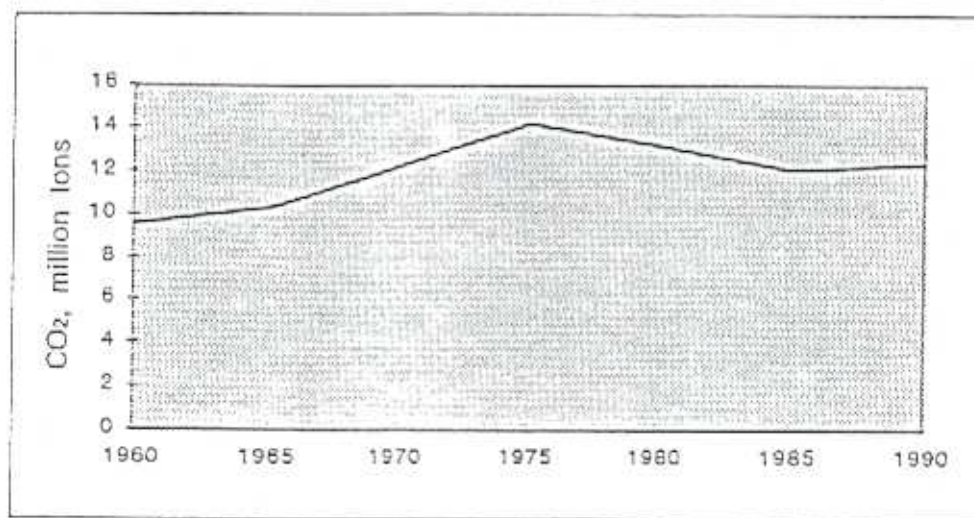


Figure 15. Iowa CO₂ Emissions from Gasoline (million tons CO₂). Calculated from Energy Information Administration (EIA) State Energy Data Report using EPA State Workbook methodology.

Limiting emissions by changing fuel taxes. One goal of state policy could be to stabilize emissions of CO₂ from gasoline. That is to say, the emissions level in 1990 could be used as a target for the year 2000. The level of emissions in 1990 was estimated to be 12.36 million tons of CO₂. The annual growth rate of VMT in Iowa from 1980 to 1993 was about 2.5 percent per year (with a declining population, the per capita VMT growth rate was about 2.8 percent per year). See Table 10.

Assuming that travel will grow from 1993 to 2000 at the same 2.5 percent growth rate, total VMT in Iowa would be 30,188 million VMT. How much CO₂ would be emitted in 2000 depends crucially on the emissions per unit of travel of the vehicle fleet in that year. About five percent of Iowa's fleet is purchased new each year, and the average new car fuel efficiency today is about 12 miles per gallon better than a new automobile a decade ago (Bureau of Transportation Statistics, 1994); by 2000, over one quarter of Iowa's automobile fleet should be much more fuel-efficient than the oldest cars in today's fleet. More research would be needed to precisely determine the magnitude of this efficiency effect.

TABLE 10
Selected trends in travel and emissions, U.S. and Iowa, 1960-1993

Year	VMT per capita (miles)		Iowa CO ₂ emissions			
	U.S.	Iowa	From gasoline*	Index with 1960=100	State total*	Share accounted for by gasoline
1960	3,994	4,082	9.59	100	11.37	84%
1961	4,029	4,158	9.73	101	11.54	84%
1962	4,125	4,236	9.87	103	11.71	84%
1963	4,269	4,364	10.01	104	11.89	84%
1964	4,423	4,485	10.15	106	12.06	84%
1965	4,588	4,644	10.29	107	12.23	84%
1966	4,760	4,866	10.90	114	13.27	82%
1967	4,872	5,064	11.50	120	14.31	80%
1968	5,096	5,368	12.11	126	15.35	79%
1969	5,318	5,541	12.71	133	16.39	78%
1970	5,499	5,669	12.26	128	15.90	77%
1971	5,753	5,800	13.32	139	17.43	76%
1972	6,091	5,939	13.78	144	18.11	76%
1973	6,198	6,179	15.06	157	19.55	77%
1974	6,101	6,046	14.17	148	18.79	75%
1975	6,173	6,197	14.25	149	18.94	75%
1976	6,476	6,363	15.15	158	19.76	77%
1977	6,719	6,530	15.36	160	20.11	76%
1978	6,957	6,671	15.44	161	20.05	77%
1979	6,809	6,502	14.49	151	19.89	73%
1980	6,713	6,282	13.24	138	18.21	73%
1981	6,751	6,414	12.65	132	17.34	73%
1982	6,864	6,668	12.44	130	17.76	70%
1983	7,039	6,786	12.74	133	17.61	72%
1984	7,260	7,053	12.36	129	17.74	70%
1985	7,459	7,104	12.05	126	17.06	71%
1986	7,641	7,336	12.07	126	16.86	72%
1987	7,929	7,526	12.19	127	17.47	70%
1988	8,286	7,888	12.57	131	18.04	70%
1989	8,494	8,123	12.66	132	18.26	69%
1990	8,622	8,342	12.36	129	18.16	68%
1991	8,615	8,449	12.48	130	17.59	71%
1992	8,781	8,709	12.25	128	17.58	70%

*In millions of tons.

SOURCES: VMT data for U.S. and Iowa from Iowa Department of Transportation, 1995. Population data from various editions of the *Statistical Abstract of the United States*, U.S. Department of Commerce, Washington, DC: 1994, Table 26; 1988, Table 21; 1986, Table 12; 1978, Table 11; 1975, Table 11; 1971, Table 12; 1966, Table 9; 1961, Table 6; 1952, Table 10; 1944-1945, Table 8. Emissions from motor gasoline in Iowa from Ney and Schnoor, 1995, p. 74.

If the policy objective was to limit total CO₂ emissions in the year 2000 to 1990 levels of 12.36 million tons, the number of miles traveled per ton of CO₂ would have to rise from 2,000 (today's level in Iowa) to about 2,442, an increase of 22 percent. Given the 40 percent improvement achieved from 1980 to 1992, it may well be possible to improve efficiencies by this amount with fleet replacement alone. To the extent that such further efficiency is not possible or realistic, total travel could be reduced by increasing fuel taxes. If efficiencies increased by 15 percent, the balance of the goal, about seven percent, could be addressed by fuel taxes.

It is important to note that the ability of changes in fuel taxes to influence overall automobile costs is rather limited, especially in comparison to earlier decades. In 1994, the cost of operating an automobile was \$4,665 per 10,000 miles, in 1990 dollars (Bureau of Transportation Statistics, 1994). Of this total cost, \$910 (19.5 percent) was related to variable costs of operating a car, primarily the purchase of gasoline and oil, maintenance, and the cost of tires. In 1975, the variable cost was \$1,566 in 1990 dollars, almost twice as high in real terms. In the late 1990s, given stable overall energy prices, it is clear that only large changes in fuel taxes have any prospect of significantly impacting the total costs of owning and operating an automobile.

Carpooling. A result of increases in fuel prices is to promote carpooling as well as a downward pressure on the overall amount of travel. Ferguson (1994) analyzed Census and Nationwide Personal Transportation Survey (NPTS) data on carpooling for the period from 1970 to 1990. Since oil prices rose significantly in the 1970s and then fell as much in the 1980s, he used a comparative statistics approach to estimate the elasticity of carpooling with respect to gasoline prices (which allows for changes in fuel efficiencies). Based on this analysis, Ferguson estimated that the elasticity of carpooling with respect to gasoline prices is 26.1 percent. That is to say, as gasoline prices change by 100 percent, carpooling will increase by .261. He further estimated that it would take an increase of 51 cents per gallon in gasoline prices to offset the ongoing decline in the carpooling rate associated with other factors and an increase of \$1.31 per gallon to restore the carpooling rate of 1980 (19.7 percent) by the year 2000 (pp. 2-10, 2-11).

A significant tax increase has a number of serious disadvantages. Rural residents do not have as many modes to choose from as their urban counterparts, and are not able to reduce their trip-making by as much. Similarly, lower income people are less able to purchase newer cars with higher fuel efficiency ratings and so may bear a large burden. Finally, there are important border issues that would arise if Iowa had a significantly higher gasoline tax than its neighbors. As the tax differential increased, the incentive to simply purchase fuel elsewhere would also increase, thus undermining the rationale for the policy. In the worst case scenario, more travel would be undertaken to evade the tax and travel patterns would remain unchanged otherwise. However, a small gas tax of 0.4¢/gallon would not be a burden on the economy, and it would raise \$32 million per year to help fund the Greenhouse Gas Action Plan. There is some logic to achieving revenues for a

Greenhouse Gas Action Plan from the fuels that emit greenhouse gasses and other air pollutants.

Discourage single occupancy vehicle trips

Although increasing fuel taxes is the most direct way to influence the relative costs that people confront when deciding to use an automobile, a number of other policy levers also discourage the use of single occupancy vehicles, especially in urban areas and for work trips.

Parking regulations and controls. In areas out of attainment with federal clean air regulations, the Clean Air Act Amendments of 1990 require that all employers with over 100 workers introduce and maintain programs to reduce the number of commute trips (Office of Air and Radiation, 1992). The goal for programs in nonattainment areas is that the average vehicle occupancy for commute trips increase by 25 percent. Even if such programs are implemented successfully, Orski questioned whether the overall impact will be very significant. Studying the Los Angeles area, he found that only 25 percent of all trips were to and from work, and only 40 percent of these were to employers with over 100 workers (Orski, 1993). A 25 percent reduction in work trips to large work sites, if achieved, would only reduce total trips by about two to three percent. While this is an important amount, it is likely to be mitigated quickly by the general trend of higher numbers of trips. Iowa currently has no nonattainment areas for ozone so significant reductions may be even more difficult to achieve.

The Principal Financial Group in Des Moines is concerned about the financial and environmental effects of their employees commuting to and from work. There are limited downtown parking spaces for employees of The Principal; 500 parking stalls will be lost to the proposed Hillside Development. In addition to the lack of parking spaces, traffic congestion, increased air pollution, and fuel savings are other important reasons why The Principal has adopted transportation policies encouraging their employees to take buses and car pool.

Combined with the 475 existing bus riders, The Principal had a total of 840 employees that commuted by bus last June. New employees of The Principal visit with bus line representatives to learn about commuting options. The Principal fully subsidizes the Des Moines Metropolitan Transit Authority (METRO) \$22 monthly bus pass for their employees and has doubled their inter-city MTA Ankeny and Five Oaks bus subsidies.

Ride-share incentives also are offered by The Principal. Quarterly drawings will be held for cash prizes: \$25 for 2 people/vehicle, \$35 for 3 people/vehicle, and \$50 for 4 people/vehicle. In addition, two employees who car pool from July 1, 1993 through December 31, 1993 will win a grand prize of \$300 in travel certificates.

Telecommuting. Telecommuting is an option that could help to revitalize small towns in Iowa. Employees spend most or part of their work time at home, and they complete their assignments and correspondence electronically by computer. Because there are relatively few commuters in Iowa compared to other states, this is not a priority option that would result in major CO₂ emission reductions, but it is a trend with companies like Principal Financial that should continue. Regional satellite offices could be established for large companies in rural Iowa (where costs are low) that would reduce commuting distances and be linked to other offices by computer.

Changing tax treatment of parking. In 1990, drivers reported that they paid nothing for parking on 99 percent of their automobile trips (Shoup, 1995). For commuting trips to work, the proportion reporting that they paid nothing fell to only four percent. Since commuting accounts for a significant share of all trips and vehicle miles, especially in peak hours, the fact that parking is provided at no cost to drivers may lead to more use of automobiles than is socially desirable.

Employer Paid Parking. A number of studies have found that the removal of employer-paid parking does have an effect on the share of work trips taken by single drivers in automobiles. Studies to investigate this phenomenon have looked at the removal of such parking (before/after study) or compared similar groups of workers with and without this benefit (with/without study). Shoup reported that seven studies from 1969 to 1991, mostly in Los Angeles, found that the modal share of solo drivers falls on average from 67 percent when employers pay for parking to 42 percent when employees pay. The price elasticity of demand is -0.15, indicating that as the price of parking increases by 100 percent, the demand for it will fall by 15 percent.

In general, no significant public policy issue arises with an employer-paid benefit such as parking. Employers and employees are free to negotiate terms of employment that both are willing to offer and accept. There are two reasons why employer-provided parking may not provide for a socially optimal level of automobile use. First, the tax treatment of employer-provided parking is not neutral. Under the tax rules in effect at the federal level in most states, the value of the parking that is provided for employees is not taxed. An employee who receives parking worth \$100 per year does not have to pay tax (either federal, state or local) on the additional income thus received. This advantage is likely to lead employers to provide parking as an employee benefit more than is socially desirable. Second, offering parking as a benefit to employees is not a uniform benefit, and favors automobile use. If an employer offers free parking to those who desire it, and nothing to those who do not, no incentive is created to use other modes, such as cycling or transit, even though society would gain through the resources *not* used to provide parking and the accompanying reduction in energy use and emissions.

In 1992, California passed legislation requiring employers who lease parking spaces for employees to offer an equivalent cash amount to all employees who do not use a space. The legislation has three important advantages:

- The price of parking is "revealed"
- Employees now have a choice and an incentive not to use parking
- Employers have little added cost, as only spaces currently leased from outside entities are affected

The state of Iowa could adopt a plan to address the effects of employer-provided parking on energy consumption and environmental emissions. The basic features of such a plan would include one or both of the following policy changes:

- Require employers to offer a "cash-out" plan for parking. Such a requirement could initially cover only spaces leased on the commercial market, or could be designed to include the cost of spaces provided by the employer directly. This second approach would require the employer to set a monetary value on such parking spaces.
- Include the value of an employer-provided parking space in an employee's taxable income. Alternatively, disallow the cost of providing such spaces as a deduction from corporate income.

The simplest change, requiring a "cash-out" for currently purchased parking spaces, would be relatively straightforward to administer. The employers involved already know the cost of parking, who parks and who does not, and offering a choice should be administratively easy. A "cash-out" policy should be relatively popular, as employees are not required to stop using automobiles but simply encouraged to consider other ways to get to work. Employers would not be burdened by extra costs above and beyond those already borne.

These changes would be more difficult to get political support for and to administer if they are also applied to parking spaces that are not currently bought and sold, or if employees' tax liabilities were to increase as a result.

A number of demonstration programs have been conducted to test the effectiveness of "cash-outs". For example, in Seattle, two demonstration programs were undertaken between 1992 and 1994 (Wong and Woo, 1994). In the first program, called "Parking Pass," workers at five major employers in downtown Seattle were offered four free or reduced cost parking vouchers each month if they bought a monthly bus pass. In the second program, "Cash in Your Car," commuters working for three employers who agreed to forgo a free or subsidized parking space were given a cash payment instead.

The "Parking Pass" program had limited success in making workers who had driven to work alone change to monthly bus passes. Of all the participants in the program (about half of all workers at the sites), the bulk had already been using buses or a mixture of modes. Only nine percent had been driving single occupancy vehicles. The program's major successes were in allowing bus riders to have a few days' parking for use when needed, and in encouraging bus riders to buy monthly passes instead of paying cash each day. The "Cash in Your Car" program was even less effective. Only 26 workers out of an estimated 277 who were eligible (e.g., sales staff, who received free parking but were not required to have a car at work) participated in the program. Most of those who enrolled used buses to commute.

When considering these findings and how they apply to Iowa, it should be stressed that the "Cash in Your Car Program" was only tested with employers located in areas where the monthly parking charge exceeded \$30. The limited appeal of the program even in this kind of environment suggests that the impact in most urban areas in Iowa would be very modest.

Iowa is much more limited in its ability to tax the value of parking since federal tax rates are so much higher. An employee who had to pay only state tax on a parking benefit would feel much less impact than if the federal government adopted this kind of policy.

Promote transit use

The most important market for public transit has traditionally been the journey to work. Job sites are often concentrated close together and the fact that many users wish to make a trip at approximately the same time of day allows transit operators to schedule services close together. Promoting increased use of transit as a way to limit automobile use will have to be successful for work trips if this strategy is to have any significant effect on overall transportation use.

Transit is used in a low share of work trips in the state of Iowa. Transit provides only 1.2 percent of all journeys to work. In the group of 24 larger cities, transit provides 2.5 percent of all trips. This average is raised by university communities in Iowa City and Ames, which have far higher transit shares (10.0 percent in Iowa City and 7.8 percent in Ames). In fact, the low overall transit share of work trips (1.2 percent statewide) masks a 0.3 percent share outside the 24 larger cities and a 2.5 percent share within them. Any policy adopted in Iowa to promote transit has to focus on larger towns in order to build on established transit systems. Introducing new systems outside these cities would be expensive and almost certain not to attract significant numbers of users.

In the short to medium term, transit use in Iowa can be promoted most effectively through one of two objectives:

- Further increase usage in communities with relatively high transit use, or

- Stimulate transit usage in communities where the current level of usage is relatively low

To have a significant effect on current modes used by Iowans, the state would need to adopt coordinated measures involving employers, parking availability, land use controls, and increased transit services. Because of the trend at the federal level to reduce support for transit services, the state would have to commit funds to increase transit services. It is probably true that improving transit use in already well served communities is more likely to be achieved, but this increase would be costly. It is realistic to expect only relatively small increases and even then, only for work trips. Currently available transit resources are unlikely to be able to perform a big role in Iowa for nonwork trips in the foreseeable future.

Improve fuel economy and vehicle emissions by regulation and improving technology

During the energy crisis of the mid-1970s, Congress adopted a regulatory policy to improve the energy efficiency of automobiles. A set of Corporate Average Fuel Efficiency (CAFE) standards were established. Automobile manufacturers had to meet a fleet-wide average level of fuel efficiency that was set for 1978 model year vehicles at 18.0 miles per gallon (mpg) for automobiles, rising to 27.5 mpg for the 1985 model year. Standards for light trucks were about one quarter lower (National Highway Traffic Safety Administration, 1993).

The improvements in fuel efficiency that CAFE standards and higher energy prices have precipitated are starting to level off. Greene notes that 1992 and 1993 probably represented two consecutive years of declines in average miles per gallon for the fleet of automobiles and light trucks in the U.S. (Greene and Fan, 1995). The increasing efficiency of each automobile has been offset by two factors:

- the number of people in each vehicle has declined, although data on average vehicle occupancy is only collected occasionally, and
- more people are buying light trucks, minivans, or vehicles with four-wheel drive.

On average, passenger cars in 1972 carried just over two people (Greene and Fan, 1995). By 1990, occupancy averaged only 1.62 people, indicating that average occupancy has fallen by 21.7 percent in two decades. The occupancy of light trucks has fallen a smaller amount, from 2.02 people per vehicle in 1972 to 1.72 in 1990, for a decline of 14.9 percent.

Light trucks and minivans comprise a larger share of new vehicle sales in the 1990s than was true in the 1970s. This trend has led fuel consumption of the new

vehicle fleet to be somewhat higher than would have been expected otherwise, given the improvement in the fuel efficiency of automobiles.

Greene estimates that the falling occupancy rate is largely responsible for keeping the level of energy use higher than would be expected given increases in fuel efficiency (Greene and Fan, 1995). Changes in buyers' preferences for light trucks have also contributed to this trend, but to a much smaller degree.

Many economists have argued that a regulatory approach such as CAFE standards is an inefficient mechanism for increasing energy conservation. For example, Nivola and Crandall (1995) contend that CAFE standards have had two effects that work counter to its intent, given a stable real cost of gasoline. First, CAFE standards have reduced the marginal cost of driving for people using new vehicles, since they are more fuel efficient. Secondly, since the standards have contributed to increasing the real cost of new vehicles, there is an incentive to keep older vehicles with low fuel efficiencies on the road longer. Instead, Nivola and Crandall argued that a policy focused on increasing the cost of fuel would have just as much impact on energy consumption but with fewer other costs. They estimate that a tax of 25 cents per gallon, if it had been introduced in 1986 as oil prices fell, would have led to as much energy saving as CAFE standards over the entire period of 1978 to 1992 (p. 56).

There are two basic problems regarding transportation in Iowa depicted in Figure 16. The top panel shows that the number of old vehicles (1982 models and older) is a relatively large fraction of the total. These older vehicles do not have efficient emission control devices for carbon monoxide, nitrogen oxides, and hydrocarbons. They also give low fuel efficiencies (low miles per gallon). Second, the trend in the mixture of vehicles sold increasingly favors multipurpose autos (vans and light trucks) with a major decrease in small, fuel efficient autos in sales since 1988. This is a federal trend that is difficult to address with state policy.

Economic incentive programs. An alternative policy mechanism to encourage people to purchase fuel efficient vehicles has been proposed by Brett Johnston at The University of Iowa Public Policy Center in 1994, entitled, "A Pricing Alternative to Achieve a More Efficient and Effective CAFE Standard". He devised a modified automobile registration system whereby purchases of new vehicles attaining greater than a specified fuel efficiency would receive a rebate. Those purchasing vehicles with less than this level of fuel efficiency would pay a fee. The rebate or fee would increase for vehicles with fuel efficiencies farther above or below the reference level. Johnston suggested that after accounting for administrative costs, the rebate/fee system should be essentially revenue neutral.

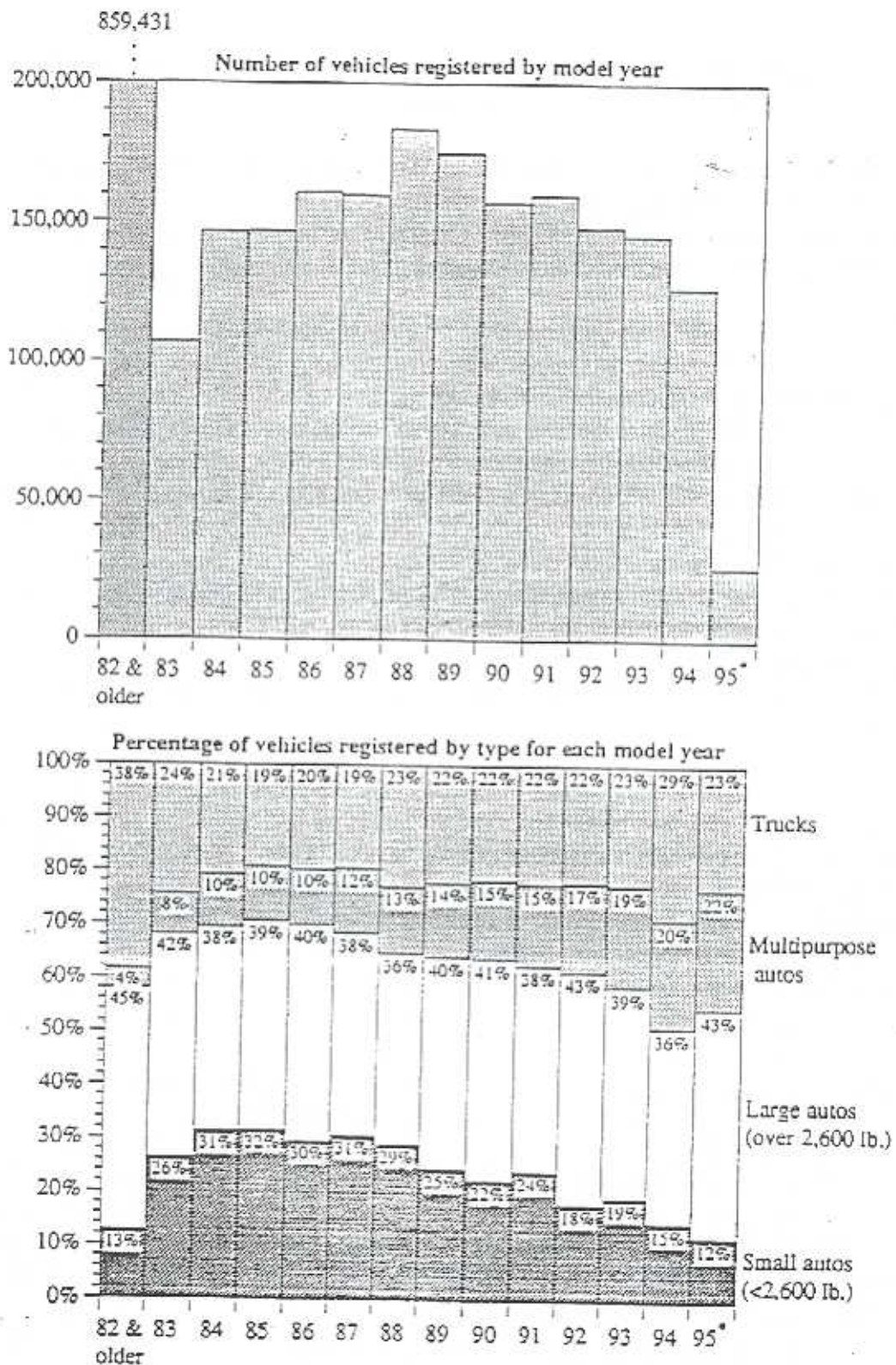


Figure 16. Registered vehicles in Iowa, by model year and type, 1994.

While this pricing system would only affect the new car fleet, it could provide a significant economic incentive to purchase fuel efficient and less polluting vehicles. Table 11 illustrates how a rebate/fee system could influence the price of new automobiles. In the table, Johnston demonstrates one possible rebate/fee schedule; the rebate or fee level is linear with the amount by which a vehicle's fuel efficiency differs from the sales-weighted average of all vehicles. Table 11 does not include all possible models of new automobiles, and as such it is only illustrative. Also, sales are national; an Iowa rebate/fee schedule should be based on prior-year sales within the state because the vehicle mix is likely to be different from that of the nation.¹

It is difficult to estimate accurately the increase in fuel efficiency a rebate/fee system such as this would contribute. It would depend on the price elasticity of demand for different classes of new vehicles. The magnitude of the impact would also depend on how aggressively the rebate/fee system is structured. If the rebate/fee system were able to raise the average fuel efficiency within Iowa by two miles per gallon by the year 2000, about one million fewer tons of CO₂ would be emitted annually.

The advantages of this pricing system are twofold. First, unlike CAFE standards, it is market based, at least to a degree. Second, it can be dynamic (e.g. as the average fuel efficiency of new vehicles increases, the reference level can be raised correspondingly).

Alternative fuel use. Another way to achieve lower emissions is to use fuels other than gasoline and diesel. Ethanol can be blended with gasoline in ratios from 85%-by-volume (E-85) down to 5%-by-volume (E-5). A recent report by the Organization for Economic Cooperation and Development (OECD) examined the air quality and greenhouse gas effects of different alternative fuels that could be adopted (European Conference of Ministers of Transport, 1993). The report concludes that governments have different policy choices depending on other policy considerations.

E-10 fuel (10% ethanol and 90% unleaded gasoline) is rapidly increasing its market penetration in Iowa. Although the total consumption is still minor, E-10 fuels have penetrated 40-45% of the market and are increasing.

In situations where self-sufficiency is important, governments should promote alternative fuels that are abundant locally, such as natural gas in Norway. If governments wish to pursue economic efficiency, then only liquefied petroleum gas (LPG) and natural gas appear desirable in some locations. If the major goal is to achieve short term environmental benefits, then natural gas and LPG look most promising. In the longer term, the most desirable sources of fuel are nonfossil fuels (if practical), along with hydrogen, electric, and fuel cell sources.

¹ It should be noted that in Johnston's example, rebates account for only 70 percent of the fees collected. Because administrative costs are not likely to be very substantial, it would be possible to raise this percentage, perhaps as high as 95 percent. Note, too, that the sales and rebate/fee figures in Table 11 are national, hence, the large values.

TABLE 11
Fees and Rebates for the 60 Top Selling Automobiles in Model Year (MY) 1993

Automobile (MY '94)	Size Class	Fuel Economy (mpg)			Vehicle Price	Fee or (Rebate)	Adjusted Price	Percentage Change	Domestic Sales (MY '93)	Revenue from Fees
		City	Hwy	Average						
Ford Taurus GL	I	19.0	28.0	23.5	\$16,140	\$507	\$16,647	3.14%	409,731	\$207,908,646
Honda Accord DX Sedan	I	22.0	30.0	26.5	\$15,060	(\$215)	\$14,845	-1.43%	329,751	(\$70,962,070)
Ford Escort 3dr	C	25.0	33.0	29.0	\$9,015	(\$700)	\$8,315	-7.78%	263,622	(\$185,369,109)
Chevrolet Lumina Coupe Euro	I	19.0	29.0	24.0	\$16,875	\$374	\$17,249	2.22%	218,144	\$81,678,281
Chevrolet Cavalier Coupe VL	C	23.0	31.0	28.0	\$8,845	(\$518)	\$8,327	-5.84%	212,374	(\$110,101,786)
Pontiac Grand Am SE Coupe	C	22.0	32.0	27.0	\$12,514	(\$700)	\$11,814	-5.6%	210,332	(\$67,310,636)
Toyota Camry Coupe DX 5M	I	21.0	28.0	24.5	\$16,148	\$247	\$16,395	1.53%	208,177	\$51,393,211
Ford Tempo 2dr GL	C	22.0	27.0	24.5	\$10,735	\$247	\$10,982	2.30%	207,173	\$51,145,351
Saturn SC	S	26.0	35.0	30.5	\$12,495	(\$958)	\$11,537	-7.66%	196,126	(\$187,299,181)
Chevrolet Beretta/Corrika Sedan	C	21.0	29.0	25.0	\$12,145	\$124	\$12,269	0.95%	166,625	\$20,732,097
Honda Civic DX Hatchback	S	29.0	36.0	32.5	\$11,780	(\$1,260)	\$10,520	-10.70%	145,367	(\$183,946,401)
Buick LeSabre Sedan	L	19.0	28.0	23.5	\$20,860	\$507	\$21,367	2.43%	138,409	\$70,229,060
Cadillac Fleetwood	L	17.0	25.0	21.0	\$33,990	\$1,267	\$35,257	3.73%	135,270	\$171,425,078
Toyota Corolla Sedan LE 4ECT	C	26.0	32.0	29.0	\$16,068	(\$700)	\$15,368	-4.37%	133,321	(\$93,746,330)
Oldsmobile Cutlass Sierra S	I	19.0	29.0	24.0	\$15,675	\$374	\$16,049	2.39%	113,292	\$43,916,903
Mercury Sable GS	I	20.0	29.0	24.5	\$17,740	\$247	\$17,987	1.39%	116,623	\$28,791,001
Lincoln Town Car Executive	L	18.0	25.0	21.5	\$34,750	\$1,101	\$35,851	3.17%	115,075	\$126,716,393
Buick Century Sedan	I	25.0	31.0	28.0	\$15,495	(\$518)	\$14,977	-3.35%	114,273	(\$59,242,946)
Nissan Sentra E 2 dr	S	26.0	35.0	30.5	\$11,694	(\$958)	\$10,736	-8.18%	113,973	(\$109,134,108)
Pontiac Grand Prix SE Sedan	I	19.0	29.0	24.0	\$16,174	\$374	\$16,548	2.31%	103,517	\$38,759,217
Pontiac Bonneville SE Sedan	L	19.0	28.0	23.5	\$20,424	\$507	\$20,931	2.48%	97,944	\$49,897,822
Mercury Grand Marquis GS	L	18.0	25.0	21.5	\$20,350	\$1,101	\$21,451	5.42%	94,607	\$104,178,189
Ford LTD Crown Victoria	L	18.0	25.0	21.5	\$19,300	\$1,101	\$20,401	5.71%	92,506	\$101,364,635
Buick Regal Custom Coupe	I	19.0	29.0	24.0	\$17,999	\$374	\$18,373	2.08%	91,672	\$34,324,168
Chevrolet Caprice Sedan	L	17.0	25.0	21.0	\$18,995	\$1,267	\$20,262	6.67%	88,972	\$112,752,510
Dodge Shadow 2dr	C	22.0	27.0	24.5	\$9,206	\$247	\$9,453	2.68%	87,074	\$21,496,191
Ford Thunderbird LX	L	18.0	25.0	21.5	\$16,830	\$1,101	\$17,931	6.54%	84,186	\$92,702,919
Geo Metro XFI Coupe	S	46.0	49.0	47.5	\$7,195	(\$2,718)	\$4,477	-37.77%	83,173	(\$226,037,730)
Mercury Topaz GS	C	22.0	27.0	24.5	\$11,270	\$247	\$11,517	2.19%	80,785	\$19,936,202
Oldsmobile Cutlass Supreme S	I	17.0	26.0	21.5	\$17,375	\$1,101	\$18,476	6.34%	80,195	\$88,308,158
Oldsmobile Eighty-Eight Royale	L	19.0	28.0	23.5	\$20,875	\$507	\$21,382	2.43%	75,317	\$38,317,508
Geo Prizm LS	C	26.0	32.0	29.0	\$11,500	(\$700)	\$10,800	-6.11%	74,346	(\$52,277,321)
Plymouth Acclaim Sedan 21A	I	22.0	27.0	24.5	\$13,170	\$247	\$13,417	1.87%	73,220	\$18,076,017
Pontiac Sunbird LE Coupe	C	23.0	31.0	27.0	\$9,764	(\$700)	\$9,064	-7.28%	72,563	(\$33,273,666)
Oldsmobile Achieva S Coupe	C	22.0	32.0	27.0	\$14,075	(\$700)	\$13,375	-5.02%	71,805	(\$22,979,090)
Plymouth Sundance 3dr	C	22.0	27.0	24.5	\$8,806	\$247	\$9,053	2.80%	66,734	\$16,474,801
Dodge Spirit Sedan 21A	I	22.0	27.0	24.5	\$13,170	\$247	\$13,417	1.87%	65,847	\$16,255,825
Ford Probe 3dr	C	22.0	31.0	26.5	\$13,883	(\$215)	\$13,668	-1.57%	63,659	(\$13,699,050)
Buick Skylark Sedan	C	22.0	32.0	27.0	\$13,949	(\$700)	\$13,249	-5.05%	63,007	(\$20,163,548)
Buick Park Avenue Sedan	L	19.0	27.0	23.0	\$26,999	\$646	\$27,645	2.39%	59,836	\$38,663,798
Chevrolet Cavalier	I	17.0	25.0	21.5	\$13,254	\$1,101	\$14,355	8.32%	56,909	\$62,566,363
Subaru Legacy L 2WD Sedan	C	21.0	27.0	24.0	\$17,050	\$374	\$17,424	2.20%	55,116	\$20,656,756
Mercury Cougar XR7	L	19.0	26.0	22.5	\$16,280	\$791	\$17,071	4.86%	54,557	\$43,159,517
Mitsubishi Eclipse	C	20.0	25.0	22.5	\$12,659	\$791	\$13,450	6.25%	53,712	\$42,491,045
Mazda 626 DX Sedan	C	23.0	31.0	27.0	\$14,255	(\$700)	\$13,555	-4.91%	52,612	(\$16,836,937)
Buick Roadmaster Sedan	L	17.0	25.0	21.0	\$23,999	\$1,267	\$25,266	5.28%	44,801	\$56,775,449
Mercury Tracer 2dr	S	25.0	33.0	29.0	\$10,250	(\$700)	\$9,550	-6.84%	43,127	(\$30,325,290)
Chrysler Lebaron Sedan LE 22P	I	20.0	28.0	24.0	\$15,121	\$374	\$15,495	2.48%	42,946	\$16,080,000
Cadillac Seville Luxury Sedan	L	16.0	25.0	20.5	\$40,999	\$1,441	\$42,440	3.52%	41,152	\$59,320,479
Lincoln Continental Executive	L	18.0	26.0	22.0	\$33,850	\$943	\$34,793	2.78%	38,458	\$36,250,723
Oldsmobile Ninety-Eight Regency	L	19.0	27.0	23.0	\$25,875	\$646	\$26,521	2.50%	35,397	\$23,001,458
Nissan Stanza Altima XE	C	21.0	29.0	25.0	\$14,699	\$124	\$14,823	0.85%	30,615	\$1,809,231
Eagle Talon DL	C	20.0	25.0	22.5	\$11,982	\$791	\$12,773	6.60%	29,911	\$23,662,304
Cadillac Eldorado Coupe	L	16.0	25.0	20.5	\$27,290	\$1,441	\$28,731	5.27%	27,527	\$39,688,084
Mazda MX-6 Coupe	C	23.0	31.0	27.0	\$17,155	(\$700)	\$16,455	-4.08%	26,555	(\$8,498,151)
Plymouth Laser Hatchback 2dr	C	20.0	25.0	22.5	\$8,806	\$791	\$9,597	8.98%	24,494	\$19,376,967
Pontiac Firebird Formula Coupe	I	19.0	28.0	23.5	\$17,995	\$507	\$18,502	2.82%	21,501	\$10,909,659
Chrysler New Yorker LHS Sedan	L	18.0	26.0	22.0	\$30,283	\$943	\$31,226	3.11%	19,761	\$18,626,827
Dodge Intrepid Sedan	I	20.0	28.0	24.0	\$17,251	\$374	\$17,625	2.17%	13,567	\$5,004,921
Mitsubishi Mirage Coupe ES	S	28.0	32.0	30.0	\$10,839	(\$876)	\$9,963	-8.08%	10,880	(\$9,526,270)
Net Revenue Generated from Fees										\$656,017,590
Gross Revenue Generated from Fees										\$2,127,195,475
Gross Revenue Paid Back to Rebates										\$1,491,177,886
Percentage of Gross Revenues Paid Back to Rebates										70%

SOURCE: Johnston, Brett. 1994. "A Pricing Alternative to Achieve a More Efficient and Effective CAFE Standard." Graduate Research Papers, University of Iowa, Iowa City, IA: University of Iowa, Public Policy Center, pp. 77-92.

The OECD researchers also conclude that, for the near future, if the goal is to decrease emissions of gases that may promote global warming, governments can only seek to "dramatically reduce overall consumption of fuels".

At present, the number of vehicles that run on alternative fuels in the U.S. is quite low but growing rapidly. In 1995, an estimated 418,000 vehicles in the U.S. used such fuels, dominated by the 299,000 LPG vehicles (Bureau of Transportation Statistics, 1995). These vehicles represented only 0.2 percent of all vehicles in use.

Advanced vehicle technology. The Office of Technology Assessment has examined the potential impact of advanced vehicle technology (Office of Technology Assessment, 1995). They used two assumptions in evaluating future designs. First, vehicles would have to have the performance characteristics of 1995 automobiles, so that vehicles with ranges of only 50 or 60 miles were not considered. Second, vehicles would have to be capable of being produced in large numbers, so that they could have a significant impact on overall emissions and fuel use.

Improvements that technology could bring about include better construction of conventional automobiles (lighter steel), use of electric vehicles, hybrid electric designs, and fuel cell vehicles. OTA concluded that the technical potential exists to have vehicles in 2015 that are 50 to 100 percent more fuel efficient than those produced in the mid-1990s. However, OTA estimates that these advanced vehicles will cost substantially more and that the potential for commercialization is therefore somewhat limited, without a substantial increase in the price of fuel.

Adopting advanced technology as a means of improving efficiency is an attractive policy because it does not directly require that fuel prices be increased as a deliberate governmental action. Nationally, progress toward limiting CO₂ emissions to 1990 levels by the year 2000 has been reported as unlikely to be achieved; the Clinton administration is pursuing an improved technical efficiency strategy as a major way to resume progress (New York Times, 1995).

In the short run, Iowa cannot significantly reduce emissions by regulating fuel or emission standards directly. The state is too small to adopt independent standards. Moreover, standards have been found to be a very blunt tool at the national level, so fuel tax changes should be used to improve efficiency if this is desired. Iowa could, however, modify its new automatic registration system to include a rebate/fee component. Alternative fuel use is unlikely to be widely adopted until well into the next century. Ethanol use has some environmental benefits but does not produce dramatic reductions in emissions, such as may be possible with hydrogen fueled or nonfossil fuel electric vehicles in decades ahead. Advanced technology is also likely to bear significant fruit in future decades and progress is likely to be driven by national policies and not those of individual states.

Railroad Freight Transportation. Nationally, there is a gradual increase occurring in trailer-on-flatcar (TOFC) railroad freight transportation. TOFC has significant implications for energy and emissions because longer so-called "unit trains" consume far less fuel on a per-ton-mile basis than semi-trailer trucks do. According to Blevins and Gibson (1991), trucks produce 3.78-times more CO₂ than unit trains. OECD places the ratio at approximately ten to one (European Conference of Ministers of Transport, 1994).

Iowa is a bridge state, meaning that enormous amounts of cargo traverse the state both east and west and north and south. To the extent that the state can facilitate rail freight transportation, the level of CO₂ emissions along major transportation corridors could be reduced greatly. To be sure, the emergence of TOFC as a means of long haul freight transportation is much more a result of market realities than public policy. Rising truck driver labor costs in particular are influencing modal choices. Yet by making rail transportation across the state as expeditious as possible, Iowa can facilitate TOFC.

Transportation Summary

A variety of public policy options exist to reduce the amount of energy consumed by the transportation sector in Iowa. Generally, such actions will result in diminished CO₂ emissions and thereby help reduce the threat of undesirable changes in climate patterns. The authors have dismissed a number of these options, focusing on approaches that could be adopted by the state of Iowa. To provide a context for the analysis, the authors first reviewed two major national documents that explore how transportation policy can help reduce CO₂ emissions. Some of the recommendations in these documents are more relevant to Iowa than others. The recommendations that are pertinent to Iowa have been taken into account in the primary analysis, i.e. policy actions that could be taken within the state.

Travel circumstances in Iowa are different from those in many other more urbanized states. While it has the nation's highest labor participation rate, the state is not dense enough to support public transit to any great extent. Almost three quarters of all work trips are in single occupant vehicles. Iowans' vehicles on average are older and less fuel efficient than is the case nationally.

Taking Iowa's travel circumstances into account, this Action Plan has analyzed four classes of policy options to reduce CO₂ emissions in the state's transportation sector. The first is to increase motor fuel taxes. We conclude that a sizable fuel tax increase would help, but by itself it probably would not greatly reduce vehicle miles of travel. This is because most rural trips are not very conducive to alternative transportation modes. Equity issues are serious, as well.

Discouraging single occupancy is a second type of policy action. Cashing out employer-provided parking has some potential in denser urban areas, of which Iowa has few. In most communities within the state, the monthly parking charge would be too small to make much of a difference in the commuting choices of employers.

A third type of policy action is to promote public transit. With only 2.5 percent modal share for transit in Iowa's 24 largest communities, a very large percentage increase in transit trips would need to occur for significant reductions in vehicle-generated CO₂ emissions to be accomplished. Worse still, the potential for any increases in transit ridership is not large. With the state's low population densities and the dispersed nature of many trips—especially those in rural areas—transit is unlikely to make significant inroads.

It is the fourth type of policy action that has the greatest potential to foster reductions in CO₂ emissions: improving vehicle fuel efficiency. One way to do this is through a modified registration system for new vehicles that involves a rebate for vehicles with comparatively high fuel efficiency and a fee for those that achieve fewer miles per gallon. Depending on how aggressively the rebate/fee system is structured, significant economic incentives can be created to purchase fuel efficient automobiles. The state can also provide incentives to motorists for them to burn relatively clean fuels. Finally, it can encourage railroad shipping by working to remove barriers such as vehicle-rail conflicts at grade crossings.

Beyond adopting public policies that directly affect travelers within its borders, Iowa can work with other states to influence the adoption of federal policies to conserve energy and reduce CO₂ emissions.

A summary of the Priority Options and Maximum Feasible Reductions that are recommended for the Transportation Sector are given in Table 12. The state program for Rebates/Fees on vehicles based on their fuel efficiency could be mandated by the State Legislature and Governor. It would be run as a revenue neutral system whereby owners of fuel efficient vehicles would be given a rebate by the State, and owners of new inefficient vehicles would be assessed a fee at the time of vehicle registration.

TABLE 12
Transportation Sector Priority Options and
Maximum Feasible Emissions Reductions
to the Year 2010 from 1990 Baseline Year

	Annual CO ₂ Reductions million tons/yr
<u>Priority Options</u>	
Vehicle efficiency (Revenue Neutral Rebate)	2.9
Discourage single occupancy trips	0.18
<u>Maximum Feasible Reductions</u>	
Vehicle efficiency (Revenue Neutral Rebate)	4.1
Discourage single occupancy trips	0.36

Utility

Emissions Trading

The Minnesota Public Utilities Commission voted on September 23, 1996 to accept a \$0.28-\$2.92/ton of CO₂ valuation for the global warming impacts/costs of carbon emissions from utility power plants. They did so on the basis of a damage-cost assessment offered by the Minnesota Pollution Control Agency – the first time in the country that anyone has established a value using such a method in a contested case. These dollar estimates are net present value estimates that account for the time value of money. It begins to establish a market value for carbon dioxide emissions that would be necessary in an emissions trading scheme.

A global, national, or regional carbon dioxide trading system could be used effectively to reduce overall greenhouse gas emissions while making pollution control a less expensive effort. Avoidance of emissions by energy efficiency would allow industries to make money by selling allowances to others.

The CO₂ Emission Allowance System could be structured similar to the sulfur dioxide allowance system that was established following the 1990 Clean Air Act Amendments. It is handled through a large mercantile exchange, the Chicago Board of Trade. Allowances would be allocated to each emitter based on their baseline CO₂ emissions. Allowances would be purchased by new and old industries seeking to expand production. They would be sold by contracting and/or innovative industries with unused allowances. Thus, emitters would develop more cost-effective measures to control CO₂, and entrepreneurs would be encouraged to develop innovative new emission control technologies. Free trading and variable price allowances would permit market forces to continually adjust the allocation of emission rights (Colton et al., 1995).

It is a difficult program for Iowa to enact alone. Rather, the state should encourage the Federal government to adopt an innovative CO₂ Emission Allowance System that would reduce carbon dioxide emissions equitably and efficiently. Deregulation of the utility industry makes market-based incentives a sound economic mechanism to obtain future emission controls in that important sector.

Nuclear Energy

Nuclear energy is generated at the Duane Arnold Energy Center at Palo, Iowa and the Mid-America Plant at Cordova, Illinois. Nuclear power results in very little greenhouse gas pollution and, thus, it helps to reduce emissions in Iowa greatly. However, due to uncertainty about nuclear waste disposal, decommissioning of plants, and public acceptability, we do not foresee new nuclear power being a viable option in the time frame of 1997-2010.

Renewable Energy

The State of Iowa has a program under the 1991 Energy Efficiency Act that requires utilities to purchase 105 megawatts (MW) of alternate-energy power (wind, alternate fuels, or biomass). A deadline was not written into the legislation, so few purchases have been made to date. Iowa is a state with abundant wind power resources, but it can only be generated at a cost of $\sim 4\text{--}6\text{¢/kW-hr}$, which is greater than coal-fired power plants burning western coal at $\$75/\text{ton}$, less than 2¢/kW-hr at existing plants. Iowa's industrial electric rates are very low in relation to surrounding states, so it is difficult to establish renewable energy sources despite the favorable setting for wind and biomass power (Table 13). However, with open access (increased competition among utilities), industrial electric rates are expected to become more uniform among States in the future which could raise Iowa utility rates to levels that would make renewable energy projects more cost competitive, especially for new generating facilities. On the other hand, if competition causes rates to be lower throughout the nation, renewable energy options would be hurt.

TABLE 13
Comparison of Industrial Electric Rates
(Source: 1994 EIA Form 861, Schedule IV)

State	Industrial Electric Rates, $\$/\text{kW-hr}$
Illinois	\$ 0.0530
Kansas	0.0491
Missouri	0.0481
South Dakota	0.0453
Minnesota	0.0433
Wisconsin	0.0383
Iowa	0.0369

Procuring renewable energy is not just a function of utility rates and the cost for wind, solar, or biomass power. It is also a function of public support and state and federal energy policies. In 1996 the State of Iowa, in effect, lost its minimum energy efficiency requirements for utilities, but it gained a revolving loan fund for renewables (Senate File SF2370). Iowa's investor-owned utilities have established a $\$5$ million revolving-loan fund over a three year period at the Iowa Energy Center to encourage development of alternate energy production facilities. Also, the Iowa Energy Center has built a model energy efficiency building to demonstrate the remarkable savings possible in residential and commercial buildings. In addition, the Iowa Utilities Board has given investor-owned utilities a deadline of February 9, 1997 to accomplish the 105 MW renewable goal.

Voluntary programs would be the favored way to achieve the expansion of renewable energy, but utilities are reluctant to invest in new programs until they see how restructuring in the industry will develop. Utilities are already investing millions of dollars in customer efficiency programs (demand side management), and these programs will continue or even expand by the year 2010. Spending on energy efficiency programs by Iowa utilities topped \$76 million in 1994 covering 226,000 residential and business customers (Weisbrod et al., 1995). Most of the benefits went to residential customers for improving lighting efficiency and HVAC (heating, ventilation, and air conditioning) equipment.

Hagler-Bailly Consultants completed a report on the Iowa economy in 1995 which showed that biomass production for electric power and energy efficiency programs were good investments for Iowa's economy. Investing \$80 million in energy efficiency programs resulted in 25 job-years per million dollars invested, \$14 million per year of new income for Iowans, and \$1.50 of additional disposable income per dollar invested. Biomass energy production from switchgrass created 84 job-years per million dollars invested and \$1.45 of additional disposable income per dollar invested. The job impact of biomass energy is particularly high, compared to energy efficiency and wind energy, because it creates a demand for a product which is produced entirely in Iowa. With increasing demand for power in Iowa, there is an opportunity for wind power and biomass industries to develop.

This Action Plan assumes that Iowa utilities will purchase 105 MW of wind power by the year 2000 and an additional 105 MW by the year 2010. Public acceptability, utility/community good-will, and lower prices for wind power will encourage the modest result.

Public Emission Inventory

In 1986 the Toxic Release Inventory (TRI) reporting program was begun under the Superfund Amendments Reauthorization Act (SARA). The TRI program requires large users of toxic chemicals to report their usage and emissions of the specified chemicals to air, land and water. These surveys are public, and they are published as top ten lists of toxic emitters within the state. In most cases, the industries on the top ten list have taken actions to reduce their emissions of these chemicals to get their facility off the list and to improve public relations. The nature of this rule is not command-and-control regulation, but rather it allows industrial sources total flexibility in achieving reductions. Nationwide, reported emissions of these toxic chemicals have been reduced by nearly 50 percent since 1987.

Under this action plan, a reporting system is proposed for greenhouse gas emissions. While greenhouse gas pollutants do not carry the social stigma that the toxic chemicals maintain, it is believed that some degree of significant emission reduction can be gained through implementation of such a program. Because the program could only be in place for a few years prior to the year 2000, annual reductions of only 1.0% will be estimated across industrial and utility sectors.

However, long range reductions could increase dramatically with proper emphasis on the results in publications, and a growing realization of the seriousness of continued greenhouse gas emissions. Annual reductions of 5% are forecast by the year 2010. It will be important to clearly identify energy efficiency through an efficiency index as well as emissions in the Public Emission Inventory, so credit is given to large utilities that have pursued energy efficiency and renewables programs.

The Energy Information Administration already promotes a Voluntary Reporting system for Greenhouse Gases (Forms EIA-1605 and 1605EZ available electronically : <http://www.eia.doe.gov>). These forms would be used to begin Iowa's CO₂ Emission Inventory. Many Iowa utilities are already participating in the Federal Climate Challenge Program where emissions are voluntarily reported.

As a part of the U.S. DOE Climate Challenge, utilities have been encouraged to work with their end-users to develop voluntary, cost-effective measures to reduce energy consumption and greenhouse gas emissions. The American Public Power Association (APPA) has provided estimates of savings to date, which show a 1.53% reduction in greenhouse gas emissions from 1990-1993. We will assume annual improvement of the savings figure at 0.5% per year by the year 2000 and 0.75% per year by the year 2010, believed to be a conservative estimate.

Table 14 is a listing of the recommended Priority Options and Maximum Feasible Reductions for the Utility Sector. These policy options are largely voluntary. Demand-side management is already an on-going utility program. The Emission Inventory could be implemented as a voluntary program or be made mandatory (requiring State Legislative action). In either case, the Inventory should be accomplished in such a way that the cost to utilities is minimal.

TABLE 14
Utility Sector Priority Options and
Maximum Feasible Emissions Reductions
to the Year 2010 from 1990 Baseline Year

	Annual CO ₂ Reductions million tons/yr
<u>Priority Options</u>	
CO ₂ Emission Inventory (1% per year)	1.4
Wind Power (105 MW) by 2000	0.28
Demand-Side Management	0.2
Emissions trading	2.0
<u>Maximum Feasible Reductions</u>	
CO ₂ Emission Inventory (5% annual reduction)	2.1
Wind Power (210 MW) by 2010	0.56
Demand-Side Management	1.0
Emissions Trading	3.5

Commercial and Industrial

Commercial Programs

The Iowa Department of Natural Resources, in partnership with federal programs, utilities, and other stakeholders has initiated various programs targeting the commercial sector which will improve Iowa's energy independence, its economy, and reduce greenhouse gas emissions. The following commercial sector programs are relevant: Building Energy Management Programs (includes the Iowa Energy Bank Program and the State of Iowa Facilities Improvement Corporation), Rebuild Iowa, and Energy Star Buildings/Green Lights.

Building Energy Management Program

The Building Energy Management Program is a comprehensive program which uses energy savings to repay financing for energy management improvements. The program serves state facilities, schools, hospitals, private colleges, and local governments by providing sound technical advice to identify potential improvements and financing to install the energy improvements expediently. Financing is structured so that energy savings cover the cost of the lease or loan payments. The program removes the most often cited barrier to implementing energy improvements -- an inadequate supply of money. Through local and regional investment banks, the program uses private funds in combination with minimal state and federal support to achieve its goals.

The overall goal of the Building Energy Management Program is to facilitate the implementation of all cost effective energy management improvements with an aggregate payback of six years or less. An investment of \$300 million in public and non profit facilities is anticipated. This investment will result in \$50 million in annual savings for Iowa's taxpayers. Additional benefits expected include creating 12,000 new jobs and the reduction of 1 million tons of CO₂, 1,600 tons of NO_x, 2,000 tons of particulate, and 18,000 tons of SO₂. To date the program has identified \$134 million in energy improvements, implemented \$90 million in improvements and is generating a cumulative annual savings of \$14 million.

Rebuild Iowa

The Rebuild Iowa Program is an opportunity for Iowa communities to create jobs, reduce pollution, improve infrastructure, and increase their quality of life. Through a federal grant, the Department of Natural Resources has competitively selected five Iowa "showcase communities" to potentially participate in the program. These communities will invest in cost-effective energy improvements in their schools, hospitals, local governments, colleges, commercial and industrial facilities, and multi-family dwellings.

Through Rebuild Iowa, communities will have the opportunity to develop self-sustaining initiatives that save energy dollars, produce economic development and additional jobs, and implement capital improvements. It is the goal of the program that every building in Iowa will have the opportunity to become energy efficient – decreasing our dependence on fossil fuels, lessening emissions, and enhancing our economy. As buildings become more efficient through Rebuild, they will serve as examples for similar facilities in other committed communities. With energy efficiency management as a priority, Iowa's communities will be rebuilt - one community at a time.

Energy Star Buildings/Green Lights

Implemented in concert with the Building Energy Management Program and Rebuild Iowa, these federal programs are designed for the commercial sector to improve efficiency in heating, cooling, and air handling equipment. The programs seek to create partnerships between utilities and commercial institutions to reduce energy demand. Estimated savings of 0.56% per year by the year 2000 and 0.83% annually by the year 2010 are predicted from baseline emissions forecasts. Iowa is not currently a participant in the program, but will incorporate into its existing programs.

Industrial Programs

The Iowa Department of Natural Resources in partnerships with utilities and other entities in the state has initiated a number of programs to serve the industrial sector. The programs include Climate Wise, the Total Assessment Audit, and Motor Challenge.

Climate Wise

Climate Wise is a voluntary program that stimulates comprehensive industrial actions to enhance energy efficiency, prevent pollution, reduce greenhouse gases, and thus, increase profits. It does so by recognizing industry's actions and by providing information and assistance on a range of emissions-reducing opportunities. Companies are encouraged to adopt creative, organization-specific measures that limit or reduce emissions such as:

- Altering production processes,
- Switching to lower-carbon-content fuels and renewable energy supplies,
- Substituting raw materials,
- Implementing employee mass transit or carpool programs,
- Auditing and tracking energy use for efficiency improvements.

Nationally stated goals of the program are to enroll 650 companies by the year 2000, representing 20% of U.S. industrial energy use with a savings goal of four quadrillion BTUs annually. Studies by the U.S. Department of Energy, the Office of

Technological Assessment, and the Alliance to Save Energy have estimated savings potentials of 12-37% for industrial energy consumption. As of June 1995, the program has received commitments from three percent of U.S. industry. Iowa projections for the impact of this program by the year 2000 are set equal to five percent of the 1990 industrial sector usage.

Total Assessment Audit

The Total Assessment Audit (TAA) is a holistic approach that encourages the pursuit of energy efficiency opportunities in industrial facilities, and in Iowa works in conjunction with the climate Wise program. The TAA encompasses a thorough review of operations, including an analysis of waste and productivity. The audit identifies ways for a customer to improve energy efficiency, reduce waste and costs, and generate greater productivity. The goal of the audits is to help industrial customers enhance their competitive position and improve their economic viability.

The Crane Valves' plant in Washington, Iowa is an example of a company using the TAA as a basis for making changes that resulted in the better use of energy resources. The audit yielded recommendations that will save the foundry operation an estimated \$302,000 each year, including \$85,800 in annual energy costs.

Motor Challenge

Motor Challenge is a 1993 US Department of Energy program which promotes energy-efficient electric motor systems, and works in concert with Iowa's industrial programs. These systems offer significant opportunities for improving efficiency throughout every sector of the economy. The Motor Challenge Program is an industry/government partnership designed to help industry capture 25 billion kilowatt hours per year of electrical savings by the year 2000.

Motor Challenge is important because electric motor systems account for almost 75% of the electricity used in industry. The program's main objectives are to increase the market penetration of efficient electric motor and drive systems in the industrial sector, improve industrial competitiveness and productivity, save energy, and decrease industrial waste and pollution. Motor Challenge will allow our nation's industries to save \$13 billion annually in energy costs by the year 2010, and these savings would result in dramatically improved competitiveness for industry and a reduction of 44 million tons of greenhouse gas emissions.

Golden Carrot

This cooperative program between utilities and manufacturers is to stimulate faster development of energy efficiency improvements in industrial heating and cooling equipment. Annual savings of 0.725% are estimated by the year 2000, and

1.09% annual savings are estimated by the year 2010. Iowa is not currently a participant in the program.

Source Reduction and Recycling has also been put forward by the federal plan as an effective means to reduce greenhouse gas emissions through reduced energy consumption. The U.S. Environmental Protection Agency is already changing methods of regulation to include source reduction as an alternative means of controlling emissions and encouraging recycling. Annual savings of 1.05% are forecast by the year 2000, and annual savings of 1.58% by the year 2010.

A summary of the recommended Priority Options and Maximum Feasible Emission Reductions for the Commercial and Industrial Sector are given in Table 15. These policy options are, for the most part, on-going and voluntary. The Emission Inventory could be voluntary or mandatory (requiring State Legislative action).

TABLE 15
Commercial and Industrial Sector Priority Options and
Maximum Feasible Emissions Reductions
to the Year 2010 from 1990 Baseline Year

	Annual CO ₂ Reductions million tons/yr
<u>Priority Options</u>	
Iowa Energy Bank and State Programs	0.08
Motor Challenge/Federal Programs/TAA	2.1
Emissions Trading	2.0
CO ₂ Emission Inventory	1.4
<u>Maximum Feasible Reductions</u>	
Iowa Energy Bank and State Programs	0.2
Motor Challenge/Federal Programs/TAA	4.2
Emissions Trading	3.4
CO ₂ Emission Inventory	2.0

State Residential Programs

Residential energy efficiency options include constructing new homes to conform with the Model Energy Code (MEC), utilizing Iowa's Home Energy Rating System (HERS), and increasing the knowledge and use of Energy Efficient Mortgages (EEMS). The Iowa State Building Energy Code is part of the State Building Code which includes the 1992 national MEC. Results from a 1994, *"Iowa Joint Utilities Task Force Residential New Construction Baseline Study"* by Kemper Management Services and Southern Electric International, indicates only 10 of the 135 homes surveyed (7 percent) passed MEC compliance. Lack of basement insulation and glass and wall insulation were the primary reasons houses failed. According to the study, the average homeowner would save about \$170 annually with properly installed basement wall insulation.

To improve implementation of existing building codes, the Iowa Department of Natural Resources, in cooperation with the Iowa Energy Center is sponsoring building energy efficiency and code education programs for builders and building officials. These programs will increase understanding and compliance with the MEC, which will increase the energy efficiency of Iowa's new home construction.

In addition, the Iowa Department of Natural Resources developed the Iowa Home Energy Rating System in a collaborative effort with Mid-Iowa Community Action, Inc. The statewide Iowa Home Energy Rating System, called Energy Rated Homes of Iowa (ERHIA), is designed so real estate agents, homeowners, home buyers, lenders and builders can systematically evaluate the energy efficiency of a home. Utility bills are the largest expense of home ownership after mortgage and tax expenses. Money saved on energy costs in energy efficient homes may be applied toward higher mortgage payments. Energy Rated Homes of Iowa can help homeowners more easily sell an energy efficient home, help homeowners make decisions about the best energy saving improvements to install, and help buyers compare homes for energy efficiency to qualify for a larger mortgage.

A home energy rating will:

- Identify areas of a home that are wasting energy and money and suggest the cost effective steps to fix those areas.
- Provide the documentation needed to take advantage of the financial incentives for buying an efficient home or improving an existing home.
- Assure that a newly constructed home meets the State Building Energy Efficiency Standard.
- Identify how efficiently a home uses energy for heating and cooling purposes, similar to the EPA rating given to cars stating the estimated miles a car will go on a gallon of gasoline.
- Give you more house for your money and more money for your house.

A comprehensive home energy rating involves an energy analyst evaluating many factors in a newly constructed or existing home to determine the overall energy efficiency of the home. Factors in this analysis include the size and type of house, construction materials used, window area and type of glass, orientation to the sun and solar gain, the tightness of the home and amount of insulation, and the type and level of efficiency being achieved by current heating, cooling, and water heating equipment. All of these factors go into the calculation of the house's total energy efficiency. The level of efficiency is expressed in a rating of one to five stars, five stars being the most efficient. A home energy rating provides a framework for developing procedures with lenders for creating energy efficient mortgages (EEMs). Homes with ratings of four stars or higher are eligible for EEMs.

U.S. Golden Carrot

Golden Carrot is a federal program to commercialize new energy efficient appliances for use in the residential sector. This program, combined with new residential standards for central air conditioners, furnaces, refrigerators, room air conditioners, water heaters, direct heating equipment, mobile home furnaces, ranges and ovens, pool heaters, televisions, and fluorescent light bulbs is predicted to achieve 0.99% annual savings in greenhouse gas emissions from the residential sector by the year 2000 and 1.49% annual savings by the year 2010.

Under the 1992 Energy Policy Act, further improvements in appliance efficiency standards are mandated, but the rules have been delayed at present. Appliance efficiency standards will generate huge emission savings during the life-cycle of those appliances, equal to about 3% of the annual projected national energy consumption. Iowa should be a leader in ensuring that federal requirements are not rolled back. Iowa will save at least 2.1 million tons/yr carbon dioxide emissions with these federal programs. With top industries such as Maytag, Amana, and Lennox, Iowa could be a leader in these programs, but it does not participate presently.

The recommended Priority Options and Maximum Feasible Emission Reductions for the Residential Sector are shown in Table 16. These programs are largely on-going and voluntary.

TABLE 16
Residential Sector Priority Options and
Maximum Feasible Emissions Reductions
to the Year 2010 from 1990 Baseline Year

	Annual CO ₂ Reductions million tons/yr
<u>Priority Options</u>	
State and Federal Programs (MEC, HERS, EEM)	0.67
<u>Maximum Feasible Reductions</u>	
State and Federal Programs (MEC, HERS, EEM)	1.3

Cross-Sector

Carbon Tax Discussion

Although greenhouse gas reduction is not the goal of a small carbon tax, a carbon tax could be a critical component of a cohesive action plan by providing a funding mechanism for implementation. The tax would also begin the process of internalizing the societal costs that polluting fuels cause through increased greenhouse gas emissions per unit of energy produced. Minnesota and Oregon are presently considering implementation of a carbon tax. As stated in "Iowa Energy Production and Use: An Inventory of Greenhouse Gas Emissions" (Ney, 1992) a carbon tax of 40 cents per ton of CO₂ emitted would raise \$31.5 million dollars annually which could fund other options to reduce greenhouse gas emissions. The impact to the typical consumer would be quite small however;

Impact on monthly residential electric bills (500 kwh/month)	32 cents/month
Impact on natural gas heating bills (220 therms/month)	53 cents/month
Impact on propane heating bills (300 gallons/month)	84 cents/month
Impact from gasoline use (100 gallons/month)	40 cents/month
Impact from diesel fuel use (100 gallons/month)	44 cents/month

The goal of a tax at this level is to begin the process of adding societal costs to polluting fuels, and as a result, cleaner alternative fuels would eventually become more economically attractive. Revenues from the tax could be used to promote renewable fuels and reforestation in Iowa. Increased development of indigenous renewable energy resources will reduce energy expenditures leaving Iowa, increase jobs, and reduce greenhouse gas emissions.

Four Scandinavian countries have adopted carbon taxes. Sweden has adopted a tax of \$70 per metric ton of carbon (approximately \$17/ton CO₂ or 17 cents per gallon of gasoline, Table 17). The Commission on Sustainable Development of the United Nations is charged with implementing Agenda 21, the ambitious action plan for the 21st century that was proposed at the 1992 Earth Summit (United Nations Conference on Environment and Development) which proposes a large carbon tax. Carbon taxes are recognized as an effective way to change consumer habits and to encourage energy efficiency, but they may also prove to be a drag on the economy. Many feel that it is better to reduce emissions by voluntary actions when possible. Thus, a carbon tax is not recommended as a Priority Option in this Plan, but the costs and benefits of such a tax are discussed here as one possible alternative for Iowa.

TABLE 17
Cost Comparisons of Sweden's Carbon Tax (\$17/ton CO₂ emitted)
to a Small Carbon Tax (\$0.4/ton CO₂) if levied in Iowa

Fuel	Sweden's Tax Taxes/fuel \$17/ton CO ₂	Small Tax Taxes/fuel \$0.40/ton CO ₂
Gasoline	17¢/gal	0.4¢/gal
Diesel	19¢/gal	0.45¢/gal
Jet Fuel	17¢/gal	0.4¢/gal
Natural Gas	10¢/ccf	0.235¢/ccf
Propane/LP	12¢/gal	0.28¢/gal
Fuel Bill	Typical Monthly Increase* Sweden's Tax	Typical Monthly Increase** Small Tax
Electric	\$13.60	\$ 0.32
Natural Gas	\$22.53	\$ 0.53
Propane	\$35.70	\$ 0.84
Gasoline	\$8.50	\$ 0.40
Diesel	\$9.35	\$ 0.44

* Typical monthly increase in fuel bill for a consumer in Iowa if Sweden's carbon tax were levied in Iowa.
Industrial coal costs in Iowa would increase by \$102 million/year
Residual fuel costs would increase by \$2.125 million/year in Iowa

** Typical monthly increase in fuel bill for a consumer in Iowa if a small carbon tax (40¢/ton CO₂ emitted) were levied in Iowa.

Funding Mechanism

This Action Plan is composed of a variety of energy efficiency measures to reduce creation of greenhouse gas emissions through fuel consumption reduction and by encouraging fuel switching, as well as a large number of renewable energy projects. The proposed options are intended to make reduction of greenhouse gas emissions in the most cost-effective manner for Iowa businesses and the people of Iowa. The programs summarized in this plan are largely voluntary in nature and many have already been underway for several years, with measurable results in terms of both economic improvement and reduction in greenhouse gas emissions. The measures will improve the Iowa economy through job and market creation, while acting to reduce health-related costs associated with pollution from fossil fuel combustion, nitrogen contamination of water supplies from agricultural run-off, or control of odors and discharges from hog-confinement operations.

The nature and intent behind the proposed actions fit ideally into the legislated objectives of the Resource Enhancement and Protection Program (REAP). Section 455A.15 (the code that establishes REAP) states:

"The general assembly finds that:

- 1. The citizens of Iowa have built and sustained their society on Iowa's air, soils, waters, and rich diversity of life. The well-being and future of Iowa depend on these natural resources"*

The REAP act further states, at section 455A.16 that

"It is the policy of the state of Iowa to protect its natural resource heritage of air, soils, waters, and wildlife for the benefit of present and future citizens... The resource enhancement program shall strongly encourage Iowans to develop a conservation ethic, and to make necessary changes in our activities to develop and preserve a rich and diverse natural environment."

The potential threats upon Iowa's natural resources posed by global climate change require attention from a society built upon those natural resources. REAP provides funds for programs similar to those set forth in this plan, including: conservation education, soil and water protection in high priority watersheds, tree and native vegetation planting, roadside planting programs, acquisitions of unique natural areas (river corridors wildlife areas, park and recreation lands, cultural resource sites), and development of wildlife management areas. All of these areas of REAP focus can be enhanced through implementation of the options presented in this Action Plan.

REAP was initially designed to be funded at \$30 million per year for ten years, but has never been funded to this level of commitment. Typical funding authorizations have been in the range of \$8-10 million per year. It is suggested that REAP funding be authorized to include an additional \$5 million to fund the measures set forth in this action plan. With the structure of REAP including activities in all 99 of Iowa's counties, the program is uniquely structured to provide the Actin Plan measures with equal benefit to all Iowans.

Summary and Conclusions

It is the purpose of this Action Plan to prepare and analyze policy options for limiting greenhouse gas emissions in Iowa and to estimate the costs, savings, and emission reductions of such a program. Iowa imports a large fraction of its energy from across its border at a cost of more than \$3.5 billion per year. It is a State with large energy use (and concomitant greenhouse gas emissions) due to a continental climate, intensive agriculture, and sparse population. Iowa can benefit greatly from future energy savings and from limiting greenhouse gases. The state has an opportunity to strengthen its economy while reducing carbon dioxide emissions.

The Iowa Greenhouse Action Plan is built on a combination of energy efficiency programs and renewable energy initiatives. This Plan includes a total of 34 options for reduction of greenhouse gas emissions (carbon dioxide, methane, and nitrous oxide), with 16 priority actions selected as the most cost-effective and easily achievable. Costs, benefits, and funding mechanisms are discussed.

Implementation of the Priority Options in this Action Plan would ensure that Iowa meets the goal of reducing its carbon dioxide emissions to 1990 levels by the year 2000. In addition, a more ambitious program of Maximum Feasible Reductions (MFR) would produce a net decrease from 1990 emissions of 23.9% by the year 2010 (Table 18). It is possible to reduce CO₂ emissions under the MFR Plan by 34 million tons/yr, or 33.9% below the baseline emissions that are projected for the year 2010 (Table 19 and Figure 17). Revenues required to enact this plan would be on the order of \$5 million per year primarily to buy trees for the reforestation program, to implement the revenue-neutral vehicle efficiency rebate system, and to establish the CO₂ emissions inventory.

Energy costs will be saved by implementation of this Plan. Energy efficiency (performing the same task with less energy) comprises about one-third of the emission reductions in the Plan. Iowa spent \$5 billion on 899 trillion BTU of energy in 1990 which produced 80.5 million tons of CO₂ (from energy only). This is an average energy cost of \$62 per ton CO₂ emitted. The total projected savings are 16 million tons CO₂ by 2010 (Table 18), and one third of that is a reduction in energy usage (the other two thirds from carbon uptake and fuel switching). Therefore, a 5 million ton reduction of CO₂ emitted per year in 2010 would represent a savings of \$300 million per year. In addition, the State of Minnesota has evaluated the environmental cost of carbon dioxide emissions in the range of \$0.28-\$2.92 per ton of CO₂. If the savings from avoiding emissions is taken as \$2/ton, then the dollars saved by this action plan would be an additional \$32 million per year (each year). Thus, the potential savings would be up to \$332 million per year, depending on the extent to which the Priority Options in this Plan are implemented. The actual net savings would depend on the total costs of implementing these programs. The

cost/benefit ratio is difficult to quantify, but it is certainly beneficial for energy efficiency options. In some cases, "who pays the cost" versus "who derives the benefits" is an issue.

Iowa strengthens its economy, creates jobs, and reduces pollution when it develops local energy resources and uses imported fuels more efficiently. Jobs are created by increased competitiveness in manufacturing; the distribution, sales, installation and service of energy efficiency equipment; and the diversification of Iowa agriculture. Iowa is in an excellent position to become a leader in the production and use of biomass and wind energy resources. It is already a leader in ethanol production from corn which has produced ~ 12,000 jobs, and it can further develop wind energy, and switchgrass and poplar plantations as new commodity crops for farmers.

Some important conclusions of the Iowa Greenhouse Gas Action Plan are:

- Emissions are projected to increase 18.5% in Iowa between 1990 and 2010 (baseline estimate). The national goal is to decrease greenhouse gas emissions to 1990 levels by the year 2000, with further reductions thereafter.
- Greenhouse gas emissions have increased since 1980 in Iowa because of increased reliance on coal (greater CO₂ emissions per million BTU than other fuels). Nevertheless, total energy consumption has remained almost constant during the period 1980-1994. Energy efficiency and fuel selection are the keys to bringing emissions under control.
- Iowans emit 29 tons of carbon dioxide emissions per person per year, the 15th highest emitting State in the U.S. on a per capita basis. All economic sectors (industrial, commercial, residential, and transportation) need improvement, but the residential sector is in special need of improvement due to a relatively old housing stock.
- Between 1986 and 1995, there has been a steady increase in energy efficiency in Iowa, as measured by the value of the Gross State Product per million BTU of energy consumption, but greater energy efficiency is possible.
- Iowa's agricultural education programs and fertilizer reduction efforts have saved \$363 million for farmers since 1985 and reduced emissions by 10.2 million tons/yr of CO₂-equivalents.
- Reforestation of 1 million acres with native forests and poplar tree buffer strips would sequester about 13.5 million tons of carbon dioxide per year or ~16% of total emissions by the year 2015.

- Various policy options shown in Table 18 demonstrate that it is possible for Iowa to meet the U.S. goal of stable greenhouse gas emissions by the year 2010, or even to reduce Iowa emissions below 1990 levels by adopting the Maximum Feasible Reduction Options.

Funding for the Greenhouse Gas Action Plan could be obtained in conjunction with the Iowa Resource Enhancement and Protection Act which states: "The citizens of Iowa have built and sustained their society on Iowa's air, soils, waters and rich diversity of life. The well-being and future of Iowa depend on these natural resources."

TABLE 18
Priority Options and Maximum Feasible Reductions in Iowa Action Plan,
in the Year 2010 (except where noted) from 1990 Baseline Year

	Priority Options	Annual CO ₂ Reductions million tons/yr	Maximum Feasible Reductions	Annual CO ₂ Reductions million tons/yr
Agriculture	Reforest 200,000 acres by 2015	2.7	Reforest 1,000,000 acres by 2015	13.5
	Energy Crops (switchgrass, poplars) 35 MW	0.09	Energy Crops (switchgrass, poplars) 100 MW	0.26
	Reduce N fertilizer 1% per yr (2000-2010)	0.4	Reduce N-fertilizer 1% per yr (2000-2010)	0.4
	Large hog lot capture of methane	0.1	Large hog lot capture of methane	0.7
Transportation	Improved farm energy efficiency	0.1	Improved farm energy efficiency	0.1
	Vehicle efficiency (revenue neutral, market-based)*	2.9	Vehicle efficiency*	4.1
	Discourage single occupancy trips*	0.18	Discourage single occupancy trips*	0.36
Utility	CO ₂ Emission Inventory (5% reduction)	1.4	CO ₂ Emission Inventory (7.5% reduction)	2.1
	Wind Power (105 MW)	0.28	Wind Power (210 MW)	0.56
	Demand-Side Management*	0.2	Demand-Side Management*	1.0
	Emissions trading	2.0	Emissions Trading	3.5
Commercial & Industrial	Iowa Energy Bank and State Programs*	0.08	Iowa Energy Bank and State Programs*	0.2
	Motor Challenge/Federal Programs/TAA*	2.1	Motor Challenge/Federal Programs/TAA*	4.2
	Emissions Trading	2.0	Emissions Trading	3.4
	CO ₂ Emission Inventory	1.4	CO ₂ Emission Inventory	2.0
Residential	State Programs (MEC, ITERS, EEM)	0.67	State Programs (MEC, ITERS, EEM)	1.3
TOTAL		16		37

*Energy-efficiency options which reduce energy costs.

TABLE 19
Summary of Carbon Dioxide Equivalent Emissions
Projected Under this Action Plan

	CO ₂ Emissions, million tons/yr		
	1990	2000	2010
Baseline	87	93	100
Priority Option	87	86	84
Max. Feasible Reductions	87	80	64

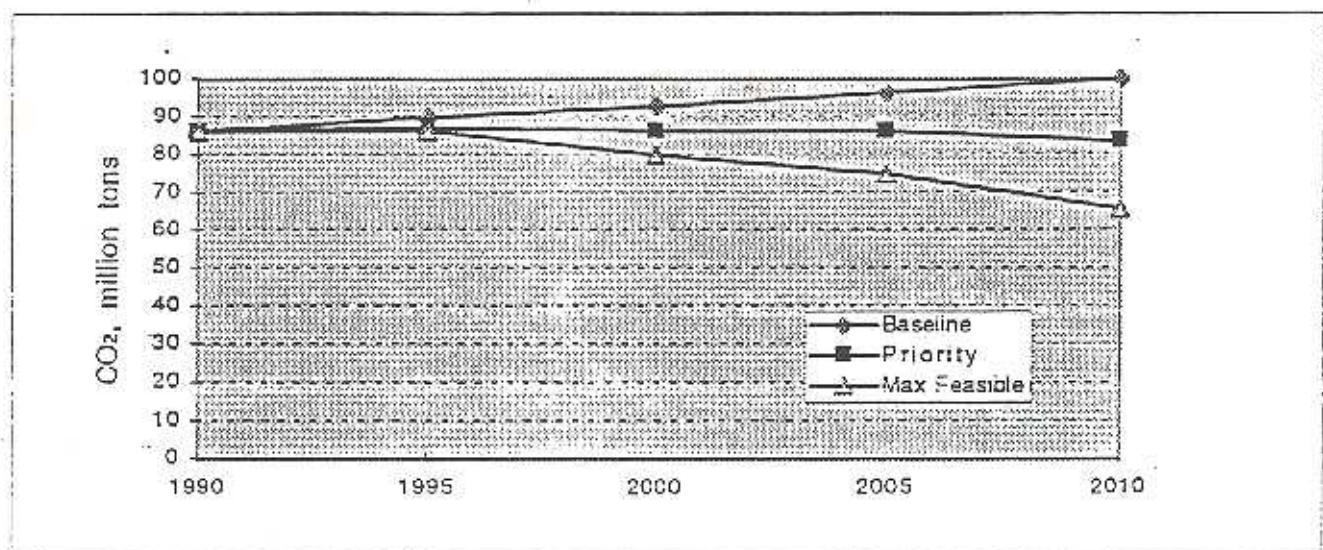


Figure 17. Comparison of Future Greenhouse Gas Emissions by Scenario (million short tons CO₂ Equivalent).

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Appendix A

Action Plan Summary Tables

TABLE A.1.
Summary of Greenhouse Gas Emissions Baseline Forecast for Iowa
CO₂ Equivalent Emissions (tons CO₂)

	1990	1995	2000	2005	2010	Est. 5- year % Increase	Notes
Fuel Combustion	80,530,000	83,992,790	87,604,480	91,371,473	95,300,446	4.30%	a
Production Processes	6,333,926	6,333,926	6,333,926	6,333,926	6,333,926	0.00%	b
Natural Gas & Oil Systems	501,600	512,635	523,913	535,439	547,219	2.20%	c
Coal Mining	3,366	1,683	842	421	210	-50.00%	d
Landfills	3,807,430	3,803,623	3,799,819	3,796,019	3,792,223	-0.10%	e
Domesticated Animals	8,364,048	8,368,230	8,372,414	8,376,600	8,380,789	0.05%	f
Manure Management	2,594,592	2,595,889	2,597,187	2,598,486	2,599,785	0.05%	g
Rice Cultivation	0	0	0	0	0	0.00%	h
Fertilizer Use	4,476,870	4,476,870	4,476,870	4,476,870	4,476,870	0.00%	i
Forest Management/ Land-Use Change	-28,075,000	-28,496,125	-28,923,567	-29,357,420	-29,797,782	5.00%	j
Burning of Ag Crop Wastes	8,162,825	8,170,988	8,179,159	8,187,338	8,195,525	0.10%	k
Wastewater Treatment	45,475	45,701	45,930	46,160	46,390	0.50%	l
Total Emissions	86,745,131	89,806,210	93,010,973	96,365,311	99,875,602		

All estimates are educated guesses based upon reasonable expectations - no citations are available except where noted below:

- a Energy use as forecast by Iowa Department of Natural Resources, Energy Bureau
- b Assumed slight growth of production
- c Per natural gas consumption estimates, IDNR Energy Bureau
- d Consistently decreasing
- e Slight decrease due to existing/planned methane collection systems & waste reduction trends - offsetting population increases
- f Animal population estimated to show only slight growth
- g Animal population estimated to show only slight growth
- h No rice production currently, or anticipated
- i Trends show relatively consistent usage
- j Trend taken from IDNR Forestry Report
- k Slight growth in acres planted
- l Slight growth due to predicted population increases

TABLE A.2.
Summary of Greenhouse Gas Emissions Implementing Priority Strategies for Iowa
CO₂ Equivalent Emissions (tons CO₂)

	1990	1995	2000	2005	2010	Est. 5- year* % Increase	Notes
Fuel Combustion	80,530,000	81,997,610	81,903,965	82,917,673	81,733,402		a
Production Processes	6,333,926	6,333,926	6,333,926	6,333,926	6,333,926	0.00%	b
Natural Gas & Oil Systems	501,600	512,635	523,913	535,439	547,219	2.20%	c
Coal Mining	3,366	1,683	842	421	210	-50.00%	d
Landfills	3,807,430	3,803,623	3,799,819	3,796,019	3,792,223	-0.10%	e
Domesticated Animals	8,364,048	8,368,230	8,372,414	8,376,600	8,380,789	0.05%	f
Manure Management	2,594,592	2,594,592	2,568,646	2,517,273	2,441,755		g
Rice Cultivation	0	0	0	0	0	0.00%	h
Fertilizer Use	4,476,870	4,476,870	4,476,870	4,454,486	4,432,101		i
Forest Management/ Land-Use Change	-28,075,000	-28,917,250	-29,784,768	-30,678,311	-31,598,660	3.00%	j
Burning of Ag Crop Wastes	8,162,825	8,162,825	8,162,825	8,162,825	8,162,825	0.00%	k
Wastewater Treatment	45,475	45,701	45,930	46,160	46,390	0.50%	l
Total Emissions	86,745,131	87,380,445	86,404,382	86,261,052	83,880,455		

* where steady rate of increase/decrease is assumed

Notes:

- a Reductions for 2000 and 2010 per sector analyses, 1995 and 2005 are taken as 35% of the respective reduction value representing implementation time and effectiveness.
- b Assumed slight growth of production
- c Per natural gas consumption estimates, IDNR Energy Bureau
- d Consistently decreasing
- e Slight decrease due to existing/planned methane collection systems & waste reduction trends - offsetting population increases
- f Animal population estimated to show only slight growth
- g No change until 2000 then slightly increasing rates of savings (1% per five year periods, 2000-2010)
- h No rice production currently, or anticipated
- i No reductions estimated through 2000; one percent savings estimated from 2000-2010
- j Double current rates of reforestation
- k No growth in crop waste burned
- l Slight growth due to predicted population increases

TABLE A.3.
Summary of Greenhouse Gas Emissions for Iowa
Implementing Maximum Feasible Reductions
CO₂ Equivalent Emissions (tons CO₂)

	1990	1995	2000	2005	2010	Est. 5- year* % Increase	Notes
Fuel Combustion	80,530,000	80,411,899	77,373,362	76,695,272	72,369,090		a
Production Processes	6,333,926	6,333,926	6,333,926	6,333,926	6,333,926	0.00%	b
Natural Gas & Oil Systems	501,600	512,635	523,913	535,439	547,219	2.20%	c
Coal Mining	3,366	1,683	842	421	210	-50.00%	d
Landfills	3,807,430	3,803,623	3,799,819	3,796,019	3,792,223	-0.10%	e
Domesticated Animals	8,364,048	8,368,230	8,372,414	8,376,600	8,380,789	0.05%	f
Manure Management	2,594,592	2,594,592	2,464,862	2,218,376	1,885,620		g
Rice Cultivation	0	0	0	0	0	0.00%	h
Fertilizer Use	4,476,870	4,476,870	4,476,870	4,253,027	4,040,375		i
Forest Management/ Land-Use Change	-28,075,000	-28,496,125	-31,887,164	-33,681,736	-39,927,863	11.90%	j
Burning of Ag Crop Wastes	8,162,825	8,170,988	8,179,159	8,187,338	8,195,525	0.00%	k
Wastewater Treatment	45,475	45,701	45,930	46,160	46,390	0.50%	l
Total Emissions	86,745,131	86,215,859	79,667,599	74,736,328	65,530,744		

*where steady rate of increase/decrease is assumed

Notes:

- a Reductions for 2000 and 2010 per sector analyses, 1995 and 2005 are taken as 35% of the respective reduction value representing implementation time and effectiveness
- b Assumed slight growth of production
- c Per natural gas consumption estimates, IDNR Energy Bureau
- d Consistently decreasing
- e Slight decrease due to existing/planned methane collection systems & waste reduction trends - offsetting population increases
- f Animal population estimated to show only slight growth
- g Steady until 2000 then 5% decrease each five year period through 2010
- h No rice production currently, or anticipated
- i No reductions estimated through 2000; on percent savings estimated by 2010
- j Growth by 11.9% each five years (250,000 acres) after 1995
- k Slight growth in acres planted
- l Slight growth due to predicted population increases

APPENDIX B

Inventory of Iowa Greenhouse Gas Emissions For The Year 1990

Phase I

Report to the Iowa Department of Natural Resources
and the U.S. Environmental Protection Agency
June 1, 1996

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EXECUTIVE SUMMARY

In 1990, the General Assembly of Iowa passed legislation directing the Iowa Department of Natural Resources (IDNR) to conduct an inventory of greenhouse gas emissions from energy production and use activities within the State of Iowa. The ensuing report, released in January of 1992, detailed those emissions by employing the best-available calculation methods to perform the estimation. As Iowa was among the first states to accomplish a study of this nature, and no federal quantification effort had been undertaken, the emission estimation methods were not fully developed nor were they universally accepted by the world community.

Recognizing the quantification difficulties faced by the states, and the need for generally accepted emission estimation methods, the United States Environmental Protection Agency (USEPA) developed a workbook for states to use in future greenhouse gas emission inventory work. The methodology described in the workbook was developed from universally accepted techniques which were presented by the Intergovernmental Panel for Climate Change (IPCC). Completion of this inventory, conducted using IPCC guidance, thus provides Iowa with a widely accepted baseline level of greenhouse gas emissions which can be used to measure the effectiveness of future attempts to slow the release of these emissions into the atmosphere.

To further the study of greenhouse gas emissions emanating from the states, the USEPA has developed a three-phase program, the Global Climate Change Outreach Program, which provides funds for conducting a three-Phase approach to reducing or mitigating greenhouse gas emissions. Phase I is the standardized baseline inventory. Phase II is the development of a state action plan for greenhouse gas emission reduction, and Phase III funds testing and evaluation of the methodologies developed in Phase II. This report is thus a function of Phase I of the program and was developed using the Second Edition of the "State Workbook: Methodologies for Estimating Greenhouse Gas Emissions."

Analysis of per capita emission data for all 50 states shows Iowa has room to improve its energy efficiency, and the fuel mix used to meet energy needs. While the most encouraging statistic from this report is that the emissions per dollar of economic output have improved (decreased) substantially for the available period of record, 1985-1989, Iowa continues to show poor performance in the residential and to a lesser extent, industrial sectors. Iowa ranks as the state with the 8th highest per capita emission in the residential sector, and 16th highest per capita emission in the industrial sector. Iowa is 15th highest in total energy-produced- CO_2 per capita.

A combination of improving energy efficiency, managing carbon uptake through reforestation, and switching to cleaner burning renewable fuels forms a potential strategy for decreasing net greenhouse gases in the future.

DISCLAIMER

This document was prepared with a grant from the U.S. Environmental Protection Agency (EPA). However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the view of the EPA.

INTRODUCTION

The earth's atmosphere provides the planet with the capability to retain energy input from the sun. This energy input manifests itself as heat, which maintains a surface temperature that is capable of sustaining life. The physical properties of the gases which constitute the earth's atmosphere allow the atmosphere to be nearly transparent to incoming short-wave radiation. This radiation is allowed to strike the earth's surface and warm the planet, allowing photosynthesis to occur, and providing the overall energy input that drives the continuance of all earthly life. Those same gases also serve to trap the outgoing long-wave radiation that is emitted from the surface of the earth during hours of darkness. This radiative cooling is felt in the diurnal cycle as nighttime temperatures fall. The blanketing effect of the atmospheric gases creates a positive energy balance where outgoing radiation equals incoming energy at a higher energy level. Thus this radiative balance maintains the earth at a temperature much higher than would otherwise occur.

The warming effect caused by the radiative properties of these gases, termed the greenhouse effect, has been a long-accepted, and time proven scientific theory. It is the expansion of this theory, which has been termed Global Climate Change or Global Warming, that has been the subject of intense debate. The introduction of vast quantities of greenhouse gases from man-made (anthropogenic) sources is causing a buildup of these gases in the atmosphere which will eventually lead to increased warming (IPCC, 1990). There have been measurable increases in the atmospheric concentrations of greenhouse gases since the industrial revolution and its associated increase in total emissions of the gases. Proponents of the warming theory point to average global temperatures that have been increasing over the past few decades, including recent years which have been the warmest years ever recorded. Opponents of the theory argue that increases in temperature have been due to natural factors other than the accumulation of greenhouse gases. Attempts to simulate the reaction of the atmosphere to future buildups of these gases have provided some rough insights into the potential for future warming. However, these models are not yet capable of simulating all of the complex processes which would occur in response to greenhouse gas buildup, and are not capable of putting a definitive end to the debate.

The remainder of this inventory report will present the standardized emission calculations performed for the State of Iowa which have been conducted per USEPA guidance. The data will be presented to parallel the structure of the USEPA State Workbook. An additional analysis is included, providing some brief summary data which indicates Iowa's efficiency. A large portion of the emissions are derived from use of energy sources. The energy data relied upon for generation of this report comes from the Energy Information Administration (EIA) which collects standardized energy production, delivery, and usage data for each of the 50 states.

THE GREENHOUSE GASES

The following descriptions of the greenhouse gases are referenced from the USEPA guidance document, "State Workbook: Methodologies for Estimating Greenhouse Gas Emissions, Second Edition."

Carbon Dioxide (CO₂). The combustion of liquid, solid, and gaseous fossil fuels is the major anthropogenic source of carbon dioxide emissions. Some other non-energy production processes (e.g., cement production) also emit notable quantities of carbon dioxide. CO₂ emissions are also a product of forest clearing and biomass burning. Atmospheric concentrations of carbon dioxide have been increasing at a rate of approximately 0.5 percent per year (IPCC, 1992), although recent measurements suggest that this rate of growth may be moderating (Kerr, 1994).

In nature, carbon dioxide is cycled between various atmospheric, oceanic, land biotic, and marine biotic reservoirs. The largest fluxes occur between the atmosphere and terrestrial biota, and between the atmosphere and surface water of the oceans. While there is a small net addition of CO₂ (i.e., a net source of CO₂) from equatorial regions, oceanic and terrestrial biota in the Northern Hemisphere, and to a lesser extent in the Southern Hemisphere, act as a net sink of CO₂ (i.e., remove more CO₂ from the atmosphere than they release) (IPCC, 1992).

Methane (CH₄). Methane is produced through anaerobic decomposition of organic matter in biological systems. Agricultural processes such as wetland rice cultivation, enteric fermentation in animals, and the decomposition of animal wastes emit methane, as does the decomposition of municipal solid waste. Methane is also emitted during the production and distribution of natural gas and oil, and is released as a by-product of coal production and incomplete fuel combustion. The atmospheric concentration of methane, which has been shown to be increasing at a rate of about 0.6 percent per year (Steele et al., 1992), may be stabilizing (Kerr, 1994).

The major sink for methane is its interaction with the hydroxyl radical (OH) in the troposphere. This interaction results in the chemical destruction of the methane compound, as the hydrogen molecules in methane combine with the oxygen in OH to form water vapor (H₂O) and CH₃. After a number of other chemical interactions, the remaining CH₃ turns into CO which itself reacts with OH to produce carbon dioxide (CO₂) and hydrogen (H).

Nitrous Oxide (N₂O). Anthropogenic sources of N₂O emissions include soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, adipic and nitric acid production, and biomass burning.

Halogenated Fluorocarbons, HFCs, and PFCs. Halogenated fluorocarbons are human-made compounds that include: chlorofluorocarbons (CFCs), halons, methyl chloroform, carbon tetrachloride, methyl bromide, and hydrochlorofluorocarbons (HCFCs). All of these compounds not only enhance the greenhouse effect, but also contribute to stratospheric ozone depletion. Under the Montreal Protocol and the Copenhagen Amendments, which control the production and consumption of these chemicals, the U.S. phased out the production and use of all halons by January 1, 1994, and will phase out production of CFCs, HCFCs, and other ozone-depleting substances by January 1, 1996. Perfluorinated carbons (PFCs) and hydrofluorocarbons (HFCs), a family of CFC and HCFC replacements not covered under the Montreal Protocol, are also powerful greenhouse gases.

Ozone (O₃). Ozone is both produced and destroyed in the atmosphere through natural processes. Approximately 90 percent resides in the stratosphere, where it controls the absorption of solar ultraviolet radiation; the remaining 10 percent is found in the troposphere and could play a significant greenhouse role. Though ozone is not

emitted directly by human activity, anthropogenic emissions of several gases influence its concentration in the stratosphere and troposphere. For example, the emission of chlorine and bromine-containing chemicals, such as the CFCs, deplete stratospheric ozone.

Increased emissions of carbon monoxide, non methane volatile organic compounds, and oxides of nitrogen have contributed to the increased production of tropospheric ozone (otherwise known as urban smog). Emissions of these gases, known as criteria pollutants, are regulated under the Clean Air Act of 1970 and subsequent amendments.

PHOTOCHEMICALLY IMPORTANT GASES

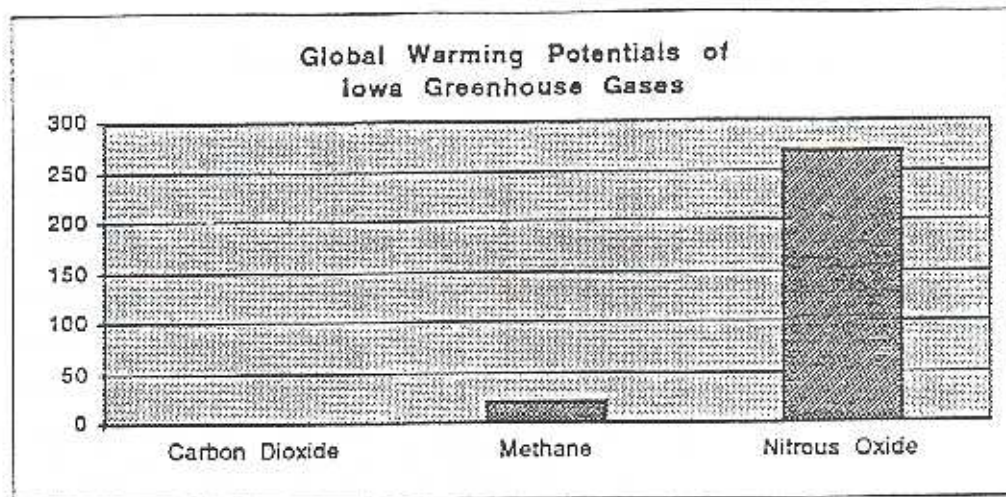
Carbon Monoxide (CO). Carbon monoxide is created when carbon-containing fuels are burned incompletely. Carbon monoxide elevates concentrations of methane and tropospheric ozone through chemical reactions with atmospheric constituents (e.g., the hydroxyl radical) that would otherwise assist in destroying methane and ozone. It eventually oxidizes to CO_2 .

Oxides of Nitrogen (NO_x). Oxides of nitrogen, NO and NO_2 , are created from lightning, biomass burning (both natural and anthropogenic fires), fossil fuel combustion, and in the stratosphere from nitrous oxide. They play an important role in climate change processes due to their contribution to the formation of ozone.

Non Methane Volatile Organic Compounds (NMVOCs). Non methane VOCs include compounds such as propane, butane and ethane. Volatile organic compounds participate along with nitrogen oxides in formation of ground-level ozone and other photochemical oxidants. VOCs are emitted primarily from transportation and industrial processes, as well as forest wildfires and non-industrial consumption of organic solvents (U.S.EPA, 1990).

GLOBAL WARMING POTENTIALS (GWP)

Each of the greenhouse gases possesses a different level of capability to produce the greenhouse effect, given a particular quantity of the gas. Therefore the international community desired a means of providing direct comparison of emissions between the various gases. To perform this comparison, the forcing capabilities of each of the gases were determined, and values were set which would convert the effects of each gas into carbon dioxide equivalent units. Thus methane, which is a more potent greenhouse gas per unit than carbon dioxide, has a multiplier of 22. This multiplier says that a unit of methane can force warming 22 times stronger than carbon dioxide. It is also important to remember that the global warming potential includes both direct effects of increased concentrations on temperature, and the best-available scientific estimate of indirect forcing. Indirect forcing can be exhibited through chemical reactions that lead to formations of products which might add to greenhouse warming.



Global Warming Potentials

Carbon Dioxide	1
Methane	22
Nitrous Oxide	270

Carbon Dioxide Emissions From Combustion of Fossil and Biomass Fuels

Carbon Dioxide (CO₂) emissions from combustion of fossil and biomass fuels were calculated using data from the State Energy Data Report which is published by the Energy Information Administration (EIA). The State Energy Data Report details fuel usage for the United States and for individual states, reporting that usage by fuel type and economic sector. Calculations for this section are conducted in spreadsheet form, beginning with the consumption figures, in trillion Btu by fuel type. Total carbon content of each fuel is then estimated using a carbon content coefficient, developed by the IPCC and presented in Table 1-3 of the State Workbook. Estimates are made to predict the amount of carbon that is held in the materials which are not combusted, such as asphalt or road oil, and these factors are applied to the total carbon content of the particular material. Next, the amount of carbon oxidized during combustion is estimated using the following data: 99 percent of carbon input to combustion from solid and liquid fuels is oxidized, 99.5 percent for natural gas, and 90 percent for wood. Finally, we convert from tons of carbon to tons of CO₂ to obtain the total estimates of emissions from fuel combustion in Iowa.

The Iowa inventory differs slightly from USEPA guidance in calculating carbon emitted from Interstate Electricity Consumption, since it was not possible to determine the exact mix of fuels used in out-of-state generation that was imported into Iowa. The EIA State Energy Data Report was used to determine a national average emission factor of carbon emissions per energy consumed in electric generation, based upon the fuel mix used for generation across the U.S. The same methodology was utilized within the Iowa data to calculate an annual emission rate per electric generation using statewide utility inputs.

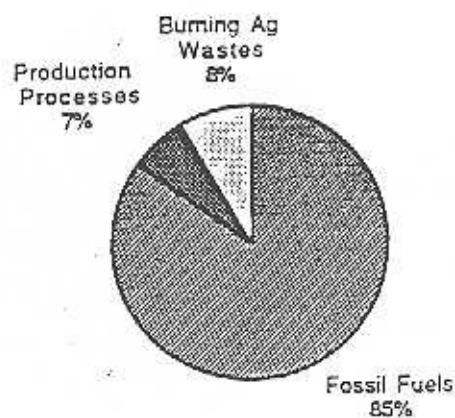
Estimates of biomass combusted in the state were obtained from the IDNR Energy Bureau 1992 Iowa Comprehensive Energy Plan, 'Toward a Sustainable Future'. No calculations appear on the biomass estimates, however, due to their extremely small nature. Some additional energy inputs have been ignored if they do not cause greenhouse gases to be emitted (such as hydropower or nuclear electric generation).

Greenhouse Gas Emissions Summary

SUMMARY TABLE FOR REPORTING EMISSIONS ESTIMATES, 1990

SOURCE	GAS	EMISSIONS (tons, on a full molecular basis)	GWP	EMISSIONS (CO ₂ - Equivalent)
Fossil Fuel Combustion	CO ₂	80,530,000	1	80,530,000
Biomass Fuel Combustion	CO ₂	N/Av	1	N/Av
Production Processes	CO ₂	6,333,926	1	6,333,926
	N ₂ O	0	270	0
	PFCs	0	5,400	0
	HFC-23	0	10,000	0
Natural Gas and Oil Systems	CH ₄	22,800	22	501,600
Coal Mining	CH ₄	153	22	3,366
Landfills	CH ₄	173,065	22	3,807,430
Domesticated Animals	CH ₄	380,184	22	8,364,048
Manure Management	CH ₄	117,936	22	2,594,592
Rice Cultivation	CH ₄	0	22	0
Fertilizer Use	N ₂ O	16,581	270	4,476,870
Forest Management and Land-Use Change* (extremely rough estimate)	CO ₂	-28,075,000	1	-28,075,000
Burning of Agricultural Crop Wastes	CO ₂	7,798,281	1	7,798,281
	CH ₄	8,507	22	187,154
	N ₂ O	657	270	177,390
	NO _x	23,746	----	
	CO	297,753	----	
Wastewater Treatment	CH ₄	2,067	22	45,474
Total Emissions (All sources, excluding biomass fuels)	CO ₂	66,587,207	1	66,587,207
	CH ₄	704,712	22	15,503,664
	N ₂ O	17,238	270	4,654,260
	NO _x	23,746	----	0
	CO	297,753	----	0
	PFCs	0	5,400	0
	HFC-23	0	10,000	0
TOTAL NET CO ₂ EQUIVALENT EMISSIONS		CO ₂		86,745,131

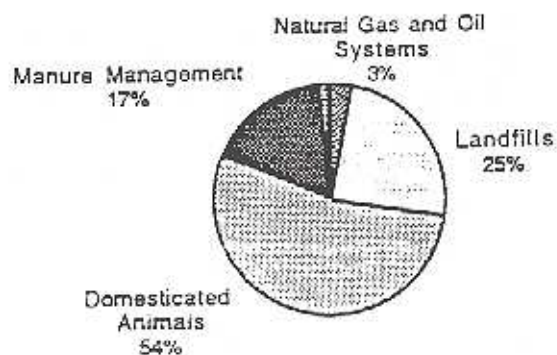
Breakdown of Carbon Dioxide Emissions From Iowa, 1990



Breakdown of Carbon Dioxide Emissions From Iowa, 1990

Fossil Fuels	80530000
Production Processes	6333926
Burning Ag Wastes	7798281

Breakdown of Methane Emissions From Iowa, 1990



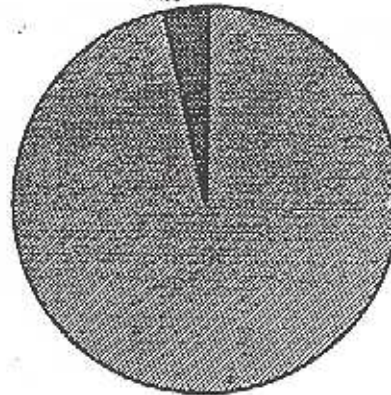
Breakdown of Methane Emissions From Iowa Significant Sources, 1990

Natural Gas and Oil Systems	22800
Coal Mining	153
Landfills	173065
Domesticated Animals	380184
Manure Management	117936
Burning Ag Wastes	8507
Wastewater Treatment	2067

Breakdown of Nitrous Oxide Emissions From Iowa, 1990

Ag Waste Burning

4%



Fertilizer Use
96%

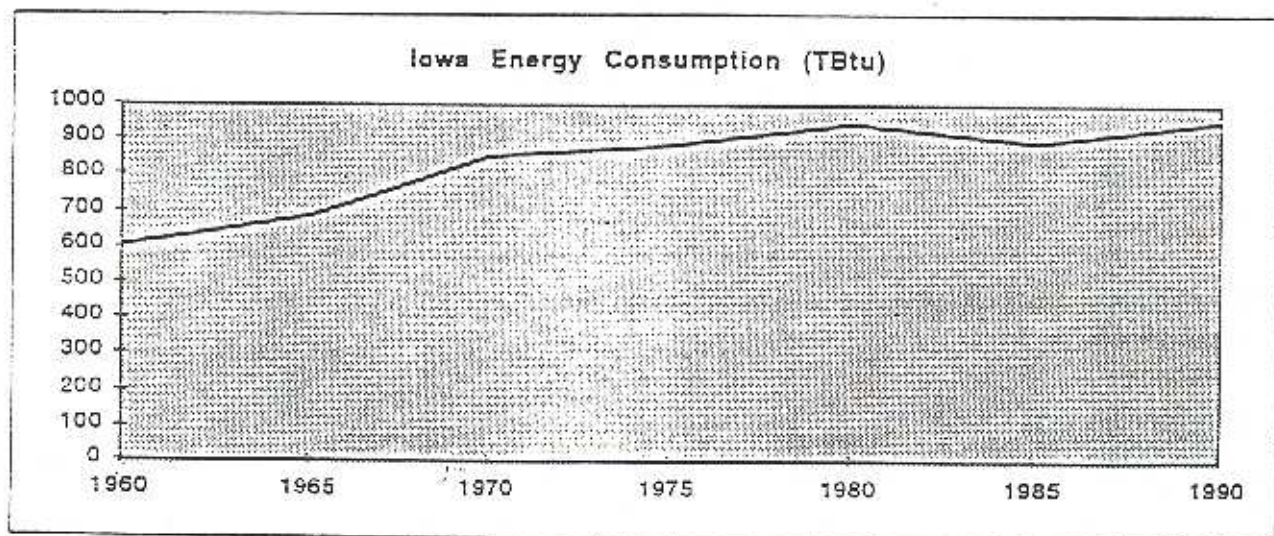
Breakdown of Nitrous Oxide Emissions From Iowa, 1990

Fertilizer Use 16581

Ag Waste Burning 657

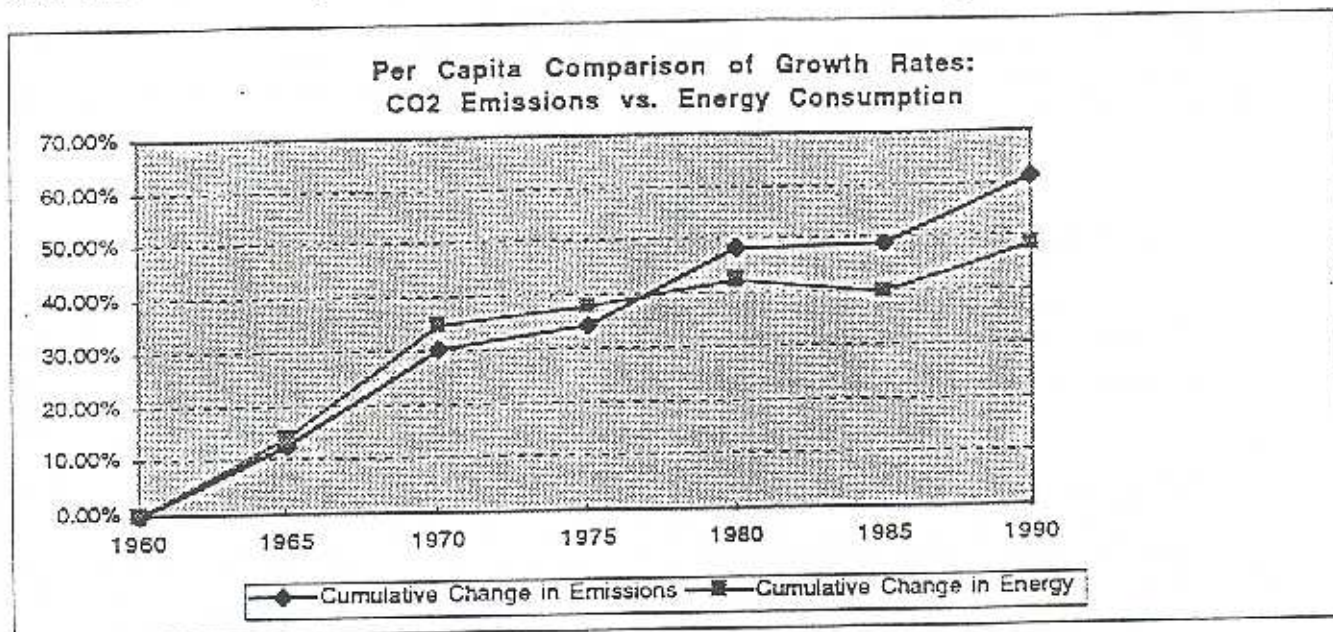
Iowa Energy Analysis

Energy consumption in Iowa has been relatively stable since the early 1970s, reflecting the combination of mostly steady economic growth and, through much of the 1970s and 1980s, an offsetting decrease in population. Recent boosts in economic activity and an upturn in population over the latest five years are leading to an increase in energy consumption and associated greenhouse gas emissions.



As can be seen in the next figure, carbon dioxide emissions tend to closely parallel the trends in energy consumption. Since the mid 1970's, however, the ratio of

carbon dioxide emissions per btu consumed has been increasing. Although new electric power generators that are currently being installed are natural gas fired, the actual consumption figures collected by EIA show a shift away from clean-burning natural gas and toward coal consumption over the past several years. In time this trend is expected to reverse.



Per capita emissions of carbon dioxide from energy consumption have risen in response to increased energy consumption. This alarming trend signals a shift away from cleaner burning fuels toward the heavy fossil fuels, mainly coal. Changes in fuel mix, like moving toward natural gas for electric generation, as well as improvements in energy efficiency and reforestation efforts will all be needed to overcome this trend.

State Comparison Statistics

In order to provide a frame of reference for assessing the magnitude of Iowa greenhouse gas emissions estimated in this inventory, a comparison has been calculated using energy consumption data for the other 49 states and the District of Columbia. The following graphics are intended to provide estimates of the relative efficiencies found in each of the economic sectors analyzed by the Energy Information Administration, in the "State Energy Data Report, 1992." Direct comparisons of per capita emission rates are made to provide a rough basis for focusing future efforts. It must be stated, however, that in some instances, direct comparison of the data do not provide insight into all possible reasons for a particular showing. Demographics, for example, is a factor which plays a very important role in energy efficiency data for a state or even a country. Areas with dispersed populations are likely to be less energy efficient than highly concentrated areas such as New York City.

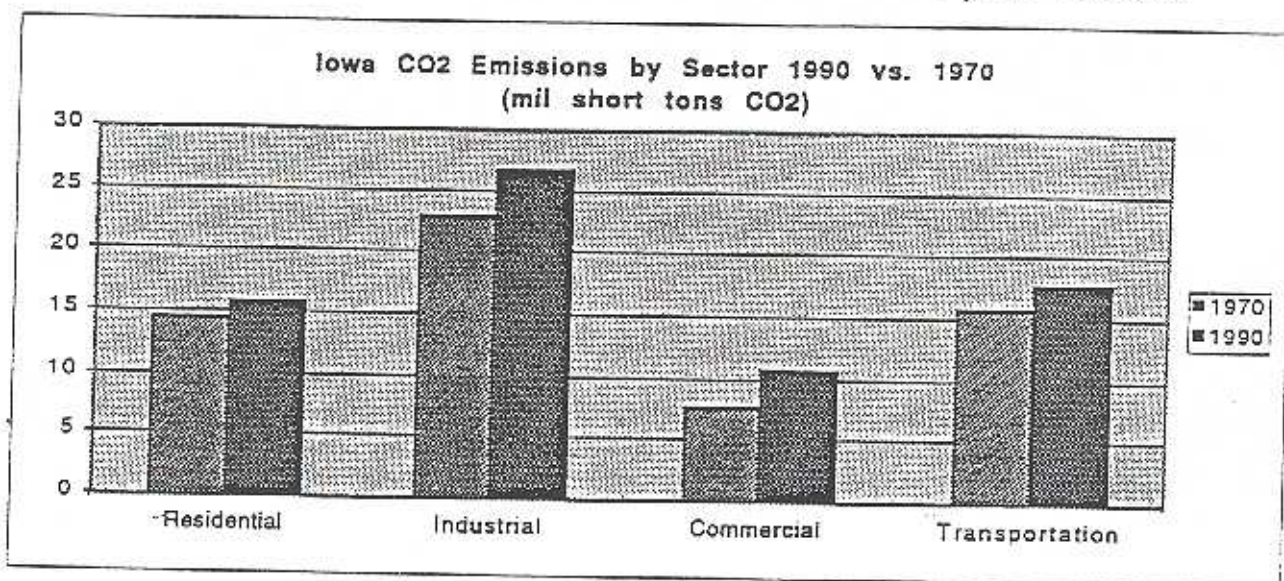
The rankings in the residential sector should be noted. Iowa has the 8th highest per capita emission of carbon dioxide from energy consumption. Relatively inexpensive utilities and old housing stock combine to produce less than efficient use of energy

resources. The Iowa industrial sector is ranked 16th highest in per capita carbon dioxide emissions. The improvement in emissions per gross state product indicates a growing efficiency in the industrial sector. Further gains in efficiency will provide emission reductions along with cost savings and higher profits.

Surprisingly, Iowa ranked only 39th highest in transportation emissions per capita. Iowa has an older vehicle stock, and with the rural nature of the state, demographics would push the state toward less efficiency in this sector, given longer travel distances. The Iowa transportation sector will be studied in more detail under Phase II of the Global Climate Change Outreach Program.

Carbon Dioxide Emissions: 1990 vs. 1970

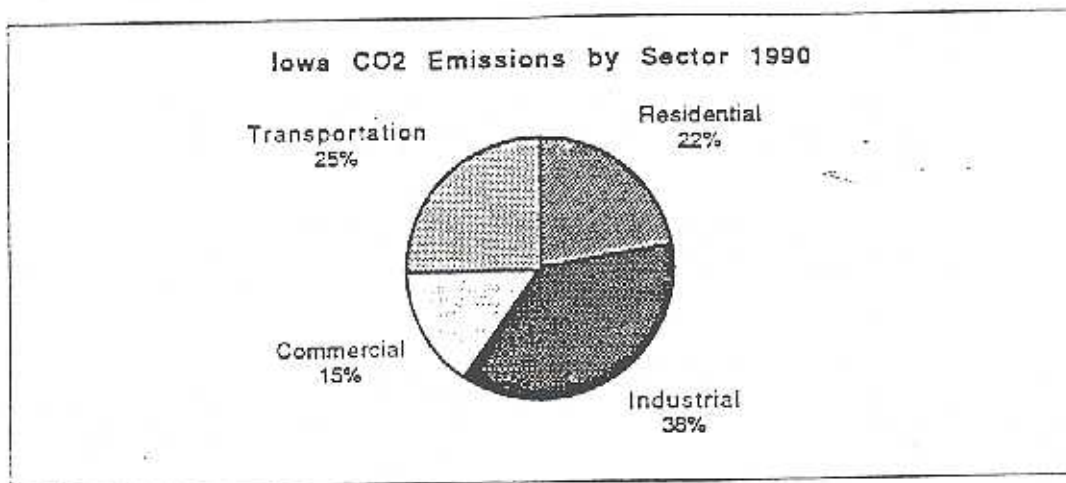
Analysis of carbon dioxide emissions by sector for two years, 1990 and 1970, indicate that energy consumption has increased and shifted within the Iowa economy.



Iowa CO2 Emissions by Sector -1990 vs.1970

	1970	1990
Residential	14.59	15.83
Industrial	22.96	26.67
Commercial	7.8	10.85
Transportation	15.9	17.97

In 1970 transportation emitted 26% of the total state emissions of greenhouse gases (from energy consumption)- by 1990, this number has decreased to 25%, despite a large increase in the number of vehicles and the miles that those vehicles are being driven. An increase in efficiency in the transportation sector has a very large incremental effect on greenhouse gas emissions, thus making it an attractive sector in which to influence the net emission of greenhouse gases in Iowa.



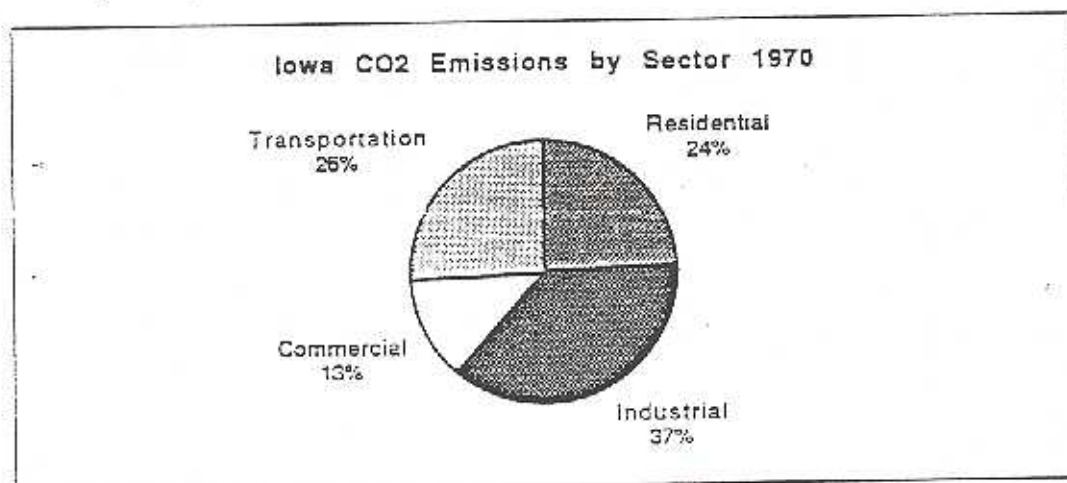
Iowa CO2 Emissions by Sector 1990

Residential	15.83
Industrial	26.67
Commercial	10.85
Transportation	17.97

87.92
 -71.32

 16.60 x Utility
 26.91

Growth of the industrial sector has led to carbon dioxide emissions that are greater than emissions from the residential and commercial sectors combined. Much needed energy efficiency gains in the residential sector, as well as urban tree-planting and reforestation programs, can be effective in reducing net emissions of greenhouse gases and improving Iowa's standing relative to other states.



Iowa CO2 Emissions by Sector 1970

Residential	14.59
Industrial	22.96
Commercial	7.8
Transportation	15.9

The growth of the residential sector contribution is also significant when you consider that the Iowa population has remained relatively steady, yet the residential sector share of energy-driven CO2 emissions has increased from 22 to 24 percent.

Iowa Energy Consumption Estimates in Physical Units

Year	Coal mmbl	Natural Gas bil cu ft	Asphalt/ Road Oil mmbl	Aviation Gasoline mmbl	Distillate Fuel mmbl	Jet Fuel mmbl	Kerosene mmbl	LPG mmbl	Lube Oil mmbl	Motor Gasoline mmbl	Residual Fuel mmbl	Other mmbl	Interstate Electricity mmkWh
1960	5,257	187.0	2,579	0.366	11,163	0.195	2,587	5,017	0.713	29,463	1,071	0.044	-2,370
1965	5,722	248.0	2,569	0.358	11,060	0.232	1,523	7,448	0.698	30,792	0.531	0.542	3,241
1970	6,168	349.0	2,914	0.256	13,677	0.725	-0.490	11,038	0.700	35,701	0.401	0.627	1,818
1971	5,898	345.0	3,120	0.281	14,257	0.655	0.372	11,139	0.585	37,325	0.414	0.899	4,691
1972	6,945	345.0	2,970	0.239	14,941	0.730	0.506	12,506	0.626	38,404	0.509	0.984	6,202
1973	7,026	365.0	2,608	0.098	15,531	0.710	0.541	12,692	0.751	42,104	0.572	1.061	9,954
1974	6,173	368.0	2,567	0.232	14,925	0.749	0.357	13,389	0.719	38,847	0.697	1.090	12,414
1975	8,407	348.0	2,294	0.191	14,553	0.835	0.214	13,845	0.655	39,042	0.608	0.986	13,729
1976	8,311	311.0	2,439	0.206	15,088	0.964	0.215	18,506	0.728	40,738	0.931	3.121	12,074
1977	9,175	280.0	2,553	0.204	15,977	1.004	0.203	17,854	0.713	41,237	1.096	3.745	14,644
1978	10,110	238.0	2,843	0.214	16,915	1.127	0.202	15,698	0.766	40,927	0.921	4.069	22,524
1979	11,352	292.0	3,154	0.191	20,711	1.039	0.460	14,686	0.801	38,501	1.216	4.962	15,647
1980	12,340	270.0	1,699	0.184	15,930	0.813	0.171	11,167	0.714	35,394	0.415	5.236	13,041
1981	13,483	253.0	1,972	0.161	14,513	0.717	0.374	9,891	0.684	34,274	0.098	2.381	14,484
1982	13,033	237.0	1,915	0.111	16,235	0.635	0.450	11,953	0.624	33,030	0.334	1.850	17,193
1983	13,540	221.0	1,603	0.100	14,099	0.591	0.089	12,028	0.653	32,396	0.207	1.623	18,752
1984	13,624	235.0	1,841	0.089	15,360	0.615	0.180	7,336	0.697	32,223	0.140	1.890	9,868
1985	14,342	226.0	2,023	0.083	15,490	0.592	0.155	8,507	0.649	31,459	0.182	1.778	6,022
1986	13,882	207.0	2,030	0.151	15,962	0.595	0.115	8,774	0.635	31,356	0.508	1.041	8,942
1987	15,191	203.0	1,788	0.110	15,762	0.779	0.110	6,098	0.719	31,814	0.117	1.069	6,760
1988	16,114	239.0	2,213	0.145	15,946	0.713	0.107	6,612	0.692	32,552	0.258	1.037	4,806
1989	17,128	228.0	1,710	0.111	14,981	0.750	0.071	7,174	0.710	32,550	0.183	1.013	3,738
1990	17,929	218.0	1,537	0.099	15,223	0.891	0.081	6,355	0.731	31,502	0.120	1.128	532
1991	18,741	233.0	1,583	0.082	14,605	0.892	0.051	7,255	0.654	32,461	0.096	1.146	-1,953
1992	17,982	231.0	1,406	0.075	16,370	0.803	0.042	8,976	0.688	31,720	0.107	1.211	388

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Trillion Btu By Fuel Type

Year	Coal	Natural Gas	Asphalt/ Road Oil	Aviation Gasoline	Distillate Fuel	Jet Fuel	Kerosene	LPG	Lube Oil	Motor Gasoline	Residual Fuel	Other	STATE TOTAL
1960	124.5	192.8	17.1	1.0	65.0	1.1	14.7	20.1	4.3	154.8	6.7	0.3	603.1
1965	135.6	255.4	17.0	1.8	64.5	1.3	8.6	29.9	4.2	161.0	3.3	3.2	696.6
1970	146.1	359.5	19.3	1.3	79.7	4.0	2.8	44.3	4.2	187.5	2.5	3.7	854.8
1971	139.7	355.4	20.7	1.3	83.0	3.6	2.1	44.7	3.5	196.1	2.6	5.2	857.9
1972	164.5	355.4	19.7	1.2	87.0	4.0	2.9	50.2	3.8	201.7	3.2	5.7	899.3
1973	168.4	378.0	17.3	0.5	90.5	3.9	3.1	50.9	4.6	221.2	3.6	6.2	944.1
1974	146.2	379.0	17.0	1.2	86.4	4.1	2.0	53.6	4.4	204.1	4.4	6.3	908.8
1975	151.8	356.4	15.2	1.0	81.8	4.6	1.2	54.7	4.0	205.1	3.8	5.7	888.3
1976	196.9	320.3	16.2	1.0	87.9	5.3	1.2	74.5	4.4	214.0	5.9	18.2	945.9
1977	217.4	208.4	15.9	1.0	93.1	5.5	1.2	71.6	4.3	216.6	6.9	21.8	944.7
1978	239.5	245.1	18.9	1.1	98.5	6.2	1.1	63.0	4.6	215.0	5.8	23.7	922.6
1979	268.9	300.8	20.9	1.0	120.6	5.7	2.6	58.9	4.9	202.2	7.6	28.9	1,023.1
1980	292.3	278.1	11.3	0.9	92.8	4.5	1.0	44.8	4.3	185.9	2.6	30.5	949.0
1981	319.4	260.8	13.1	0.8	84.5	4.0	2.1	39.7	4.1	180.0	0.6	13.9	922.9
1982	308.8	244.1	12.7	0.6	91.6	3.5	2.6	47.9	3.8	173.5	2.1	10.8	904.9
1983	320.8	227.6	10.6	0.6	82.1	3.3	0.5	48.2	4.0	170.1	1.3	9.5	878.6
1984	322.8	242.1	12.2	0.4	89.5	3.4	1.0	29.4	4.2	169.3	0.9	11.0	888.2
1985	339.8	232.8	13.4	0.4	90.2	3.3	0.9	34.1	3.9	165.2	1.1	10.4	895.6
1986	328.4	213.2	13.5	0.8	93.0	3.3	0.7	35.2	3.9	164.7	3.2	6.1	865.8
1987	359.9	209.1	11.9	0.6	91.8	4.3	0.8	24.5	4.4	165.1	0.7	6.2	880.0
1988	381.7	246.2	14.7	0.7	92.9	3.9	0.6	26.5	4.2	171.0	1.6	6.0	950.1
1989	405.7	232.8	11.3	0.6	87.1	4.1	0.4	28.8	4.3	171.0	1.2	5.9	953.2
1990	424.7	224.5	10.2	0.5	86.7	4.9	0.5	25.5	4.4	165.5	0.8	0.6	956.0
1991	444.0	240.0	10.4	0.4	85.1	4.9	0.3	29.1	4.0	170.5	0.6	6.7	995.9
1992	428.2	237.9	9.3	0.4	95.4	4.4	0.2	38.0	4.0	166.6	0.7	7.1	980.3

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Total Carbon Content By Fuel Type (million tons Carbon)

Year	Coal	Natural Gas	Asphalt/ Road Oil	Aviation Gasoline	Distillate Fuel	Jet Fuel	Kerosene	LPG	Lube Oil	Motor Gasoline	Residual Fuel	Other	STATE TOTAL
1960	3.61	3.07	0.39	0.04	1.43	0.02	0.32	0.38	0.10	3.31	0.16	0.01	12.83
1965	3.92	4.07	0.39	0.04	1.42	0.03	0.19	0.56	0.09	3.46	0.08	0.07	14.33
1970	4.23	5.73	0.44	0.03	1.75	0.09	0.06	0.84	0.09	4.01	0.06	0.08	17.41
1971	4.04	5.07	0.47	0.03	1.03	0.08	0.05	0.84	0.08	4.20	0.06	0.12	17.46
1972	4.78	5.67	0.45	0.03	1.91	0.09	0.06	0.95	0.08	4.32	0.08	0.13	18.52
1973	4.82	6.00	0.39	0.01	1.99	0.09	0.07	0.96	0.10	4.73	0.09	0.14	19.38
1974	4.23	6.05	0.39	0.02	1.90	0.09	0.04	1.01	0.10	4.37	0.10	0.14	18.45
1975	4.39	5.68	0.35	0.02	1.86	0.10	0.03	1.03	0.09	4.39	0.09	0.13	18.17
1976	5.70	5.11	0.37	0.02	1.93	0.12	0.03	1.41	0.10	4.58	0.14	0.40	19.90
1977	6.29	4.60	0.39	0.02	2.05	0.12	0.03	1.35	0.10	4.64	0.16	0.48	20.22
1978	6.93	3.91	0.43	0.02	2.17	0.14	0.02	1.19	0.10	4.60	0.14	0.52	20.18
1979	7.79	4.80	0.48	0.02	2.65	0.12	0.06	1.11	0.11	4.33	0.18	0.64	22.28
1980	8.46	4.44	0.26	0.02	2.04	0.10	0.02	0.85	0.10	3.98	0.06	0.67	20.99
1981	9.25	4.16	0.30	0.02	1.86	0.09	0.05	0.75	0.09	3.85	0.01	0.31	20.72
1982	8.94	3.03	0.29	0.01	2.08	0.08	0.06	0.91	0.08	3.71	0.05	0.24	20.34
1983	9.29	3.63	0.24	0.01	1.81	0.07	0.01	0.91	0.09	3.64	0.03	0.21	19.94
1984	9.34	3.86	0.29	0.01	1.97	0.07	0.02	0.56	0.09	3.62	0.02	0.24	20.09
1985	9.84	3.71	0.31	0.01	1.99	0.07	0.02	0.64	0.09	3.54	0.03	0.23	20.46
1986	9.51	3.40	0.31	0.02	2.05	0.07	0.01	0.67	0.09	3.52	0.08	0.13	19.85
1987	10.42	3.33	0.27	0.01	2.02	0.09	0.01	0.46	0.10	3.55	0.02	0.14	20.43
1988	11.05	3.93	0.33	0.02	2.04	0.09	0.01	0.50	0.09	3.66	0.04	0.13	21.89
1989	11.75	3.71	0.26	0.01	1.92	0.09	0.01	0.54	0.10	3.68	0.03	0.13	22.20
1990	12.30	3.58	0.23	0.01	1.95	0.11	0.01	0.48	0.10	3.54	0.02	0.14	22.47
1991	12.85	3.83	0.24	0.01	1.87	0.11	0.01	0.55	0.09	3.65	0.01	0.15	23.36
1992	12.34	3.79	0.21	0.01	2.10	0.10	0.01	0.68	0.09	3.57	0.02	0.16	23.06

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Carbon Available for Combustion By Fuel Type (million tons Carbon)

Year	Coal	Natural Gas	Asphalt/ Road Oil	Aviation Gasoline	Distillate Fuel	Jet Fuel	Kerosene	LPG	Lube Oil	Motor Gasoline	Residual Fuel	Other	STATE TOTAL
1960	3.61	3.07	0.00	0.04	1.43	0.02	0.32	0.38	0.05	3.31	0.16	0.01	12.39
1965	3.92	4.07	0.00	0.04	1.42	0.03	0.19	0.56	0.05	3.45	0.00	0.07	13.99
1970	4.23	5.73	0.00	0.03	1.75	0.09	0.06	0.83	0.05	4.01	0.06	0.08	16.92
1971	4.04	5.67	0.00	0.03	1.83	0.08	0.05	0.84	0.04	4.20	0.06	0.11	16.94
1972	4.76	5.67	0.00	0.03	1.91	0.09	0.06	0.94	0.04	4.32	0.08	0.12	18.02
1973	4.02	6.00	0.00	0.01	1.59	0.09	0.07	0.95	0.05	4.73	0.09	0.13	18.92
1974	4.23	6.05	0.00	0.02	1.50	0.09	0.04	1.00	0.05	4.37	0.10	0.14	18.00
1975	4.39	5.68	0.00	0.02	1.68	0.10	0.03	1.02	0.04	4.39	0.09	0.13	17.76
1976	5.70	5.11	0.00	0.02	1.93	0.12	0.03	1.39	0.05	4.58	0.14	0.40	19.46
1977	6.29	4.60	0.00	0.02	2.05	0.12	0.03	1.34	0.05	4.64	0.16	0.48	19.77
1978	6.93	3.91	0.00	0.02	2.17	0.14	0.02	1.18	0.05	4.60	0.14	0.52	19.68
1979	7.79	4.80	0.00	0.02	2.65	0.12	0.06	1.10	0.05	4.33	0.18	0.63	21.73
1980	8.46	4.44	0.00	0.02	2.04	0.10	0.02	0.84	0.05	3.98	0.08	0.63	20.67
1981	9.25	4.16	0.00	0.02	1.86	0.09	0.05	0.74	0.05	3.65	0.01	0.30	20.37
1982	8.94	3.89	0.00	0.01	2.08	0.08	0.06	0.90	0.04	3.71	0.05	0.23	19.99
1983	9.29	3.63	0.00	0.01	1.81	0.07	0.01	0.90	0.04	3.64	0.03	0.21	19.64
1984	9.34	3.86	0.00	0.01	1.97	0.07	0.02	0.55	0.05	3.62	0.02	0.24	19.76
1985	9.84	3.71	0.00	0.01	1.99	0.07	0.02	0.64	0.04	3.54	0.03	0.23	20.10
1986	9.51	3.40	0.00	0.02	2.05	0.07	0.01	0.66	0.04	3.52	0.08	0.13	19.49
1987	10.42	3.33	0.00	0.01	2.02	0.09	0.01	0.46	0.05	3.55	0.02	0.14	20.10
1988	11.05	3.93	0.00	0.02	2.04	0.09	0.01	0.50	0.05	3.66	0.04	0.13	21.51
1989	11.75	3.71	0.00	0.01	1.92	0.09	0.01	0.54	0.05	3.66	0.03	0.13	21.89
1990	12.30	3.58	0.00	0.01	1.95	0.11	0.01	0.48	0.05	3.54	0.02	0.14	22.19
1991	12.85	3.83	0.00	0.01	1.07	0.11	0.01	0.54	0.04	3.65	0.01	0.15	23.07
1992	12.34	3.79	0.00	0.01	2.10	0.10	0.01	0.67	0.05	3.57	0.02	0.15	22.80

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Carbon Oxidized From Energy Uses (million tons Carbon)

Year	Coal	Natural Gas	Asphalt/ Road Oil	Aviation Gasoline	Distillate Fuel	Jet Fuel	Kerosene	LPG	Lube Oils	Motor Gasoline	Residual Fuel	Other	STATE TOTAL
1960	3.57	3.08	0.00	0.04	1.42	0.02	0.32	0.37	0.05	3.28	0.16	0.01	12.27
1965	3.89	4.05	0.00	0.04	1.40	0.03	0.19	0.55	0.05	3.43	0.08	0.07	13.75
1970	4.19	5.70	0.00	0.03	1.74	0.09	0.05	0.82	0.05	3.97	0.08	0.00	16.75
1971	4.00	5.64	0.00	0.03	1.81	0.08	0.05	0.83	0.04	4.15	0.06	0.11	16.77
1972	4.72	5.64	0.00	0.02	1.90	0.09	0.06	0.93	0.04	4.27	0.08	0.12	17.84
1973	4.77	5.97	0.00	0.01	1.97	0.08	0.07	0.94	0.05	4.69	0.08	0.13	18.73
1974	4.19	6.02	0.00	0.02	1.88	0.09	0.04	0.99	0.05	4.32	0.10	0.14	17.82
1975	4.35	5.65	0.00	0.02	1.85	0.10	0.03	1.01	0.04	4.34	0.09	0.12	17.59
1976	5.64	5.03	0.00	0.02	1.91	0.11	0.03	1.38	0.05	4.53	0.14	0.39	19.27
1977	6.23	4.53	0.00	0.02	2.03	0.12	0.02	1.33	0.05	4.59	0.16	0.47	19.57
1978	8.80	3.89	0.00	0.02	2.15	0.13	0.02	1.17	0.05	4.55	0.14	0.51	19.48
1979	7.71	4.77	0.00	0.02	2.63	0.12	0.06	1.09	0.05	4.28	0.18	0.62	21.52
1980	8.38	4.41	0.00	0.02	2.02	0.10	0.02	0.83	0.05	3.94	0.08	0.66	20.46
1981	9.15	4.14	0.00	0.02	1.84	0.09	0.05	0.73	0.05	3.81	0.01	0.30	20.17
1982	8.85	3.87	0.00	0.01	2.08	0.08	0.05	0.89	0.04	3.68	0.05	0.23	19.79
1983	9.19	3.61	0.00	0.01	1.79	0.07	0.01	0.89	0.04	3.60	0.03	0.20	19.44
1984	9.25	3.84	0.00	0.01	1.95	0.07	0.02	0.55	0.05	3.59	0.02	0.24	19.56
1985	9.74	3.69	0.00	0.01	1.97	0.07	0.02	0.63	0.04	3.50	0.03	0.22	19.90
1986	9.41	3.38	0.00	0.02	2.03	0.07	0.01	0.65	0.04	3.49	0.07	0.13	19.29
1987	10.31	3.32	0.00	0.01	2.00	0.09	0.01	0.45	0.05	3.52	0.02	0.13	19.90
1988	10.94	3.91	0.00	0.02	2.02	0.08	0.01	0.49	0.05	3.62	0.04	0.13	21.29
1989	11.03	3.69	0.00	0.01	1.90	0.09	0.01	0.53	0.05	3.62	0.03	0.13	21.67
1990	12.17	3.59	0.00	0.01	1.93	0.11	0.01	0.47	0.05	3.51	0.02	0.14	21.96
1991	12.72	3.81	0.00	0.01	1.85	0.11	0.01	0.54	0.04	3.61	0.01	0.14	22.84
1992	12.22	3.78	0.00	0.01	2.08	0.10	0.01	0.67	0.04	3.53	0.02	0.15	22.57

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Carbon Dioxide From Energy Uses (million tons CO2)

Year	Coal	Natural Gas	Asphalt/ Road Oil	Aviation Gasoline	Distillate Fuel	Jet Fuel	Kerosene	LPG	Lube Oils	Motor Gasoline	Residual Fuel	Other	STATE TOTAL
1960	13.03	11.21	0.00	0.14	5.19	0.08	1.16	1.37	0.18	12.02	0.58	0.02	44.98
1965	14.25	14.86	0.00	0.14	5.15	0.10	0.68	2.03	0.17	12.57	0.29	0.25	50.40
1970	15.35	20.92	0.00	0.10	6.36	0.32	0.22	3.01	0.17	14.57	0.22	0.29	61.41
1971	14.68	20.60	0.00	0.10	6.63	0.29	0.17	3.03	0.14	15.23	0.22	0.41	61.48
1972	17.29	20.66	0.00	0.09	6.95	0.32	0.23	3.41	0.15	15.67	0.28	0.45	65.41
1973	17.49	21.88	0.00	0.04	7.22	0.31	0.24	3.46	0.18	17.18	0.31	0.49	68.69
1974	15.37	22.06	0.00	0.09	6.90	0.33	0.16	3.64	0.18	15.85	0.38	0.50	66.33
1975	15.95	20.74	0.00	0.07	6.77	0.36	0.10	3.72	0.16	15.93	0.33	0.45	64.48
1976	20.69	18.64	0.00	0.08	7.02	0.42	0.10	5.06	0.18	16.62	0.50	1.44	70.66
1977	22.84	15.78	0.00	0.08	7.43	0.44	0.09	4.86	0.18	16.83	0.59	1.72	71.76
1978	25.17	14.25	0.00	0.08	7.87	0.49	0.09	4.28	0.19	16.70	0.50	1.87	71.43
1979	29.26	17.50	0.00	0.07	9.63	0.45	0.21	4.00	0.20	15.71	0.66	2.29	78.89
1980	30.72	16.18	0.00	0.07	7.41	0.35	0.08	3.04	0.18	14.44	0.22	2.41	75.03
1981	33.57	15.16	0.00	0.06	6.75	0.31	0.17	2.69	0.17	13.99	0.05	1.10	73.94
1982	32.45	14.20	0.00	0.04	7.55	0.28	0.20	3.26	0.15	13.48	0.18	0.85	72.57
1983	33.71	13.25	0.00	0.04	6.56	0.26	0.04	3.28	0.16	13.22	0.11	0.75	71.30
1984	33.92	14.09	0.00	0.03	7.15	0.27	0.08	2.00	0.17	13.15	0.08	0.87	71.72
1985	35.71	13.55	0.00	0.03	7.21	0.26	0.07	2.32	0.16	12.84	0.10	0.82	72.98
1986	34.61	12.41	0.00	0.05	7.43	0.26	0.05	2.39	0.16	12.80	0.27	0.48	70.74
1987	37.82	12.17	0.00	0.04	7.33	0.34	0.05	1.66	0.18	12.90	0.06	0.49	72.98
1988	40.12	14.32	0.00	0.06	7.42	0.31	0.05	1.80	0.17	13.28	0.14	0.40	78.07
1989	42.64	13.55	0.00	0.04	6.96	0.33	0.03	1.95	0.17	13.29	0.10	0.47	79.45
1990	44.64	13.07	0.00	0.04	7.08	0.39	0.04	1.73	0.18	12.05	0.07	0.52	80.53
1991	46.66	13.97	0.00	0.03	6.79	0.39	0.02	1.98	0.16	13.25	0.05	0.53	83.75
1992	44.79	13.85	0.00	0.03	7.62	0.35	0.02	2.45	0.16	12.94	0.06	0.56	82.75

Iowa Energy Data from Energy Information Administration, "State Energy Data Report"

Iowa Carbon Oxidized From Energy Uses (million metric tons Carbon)

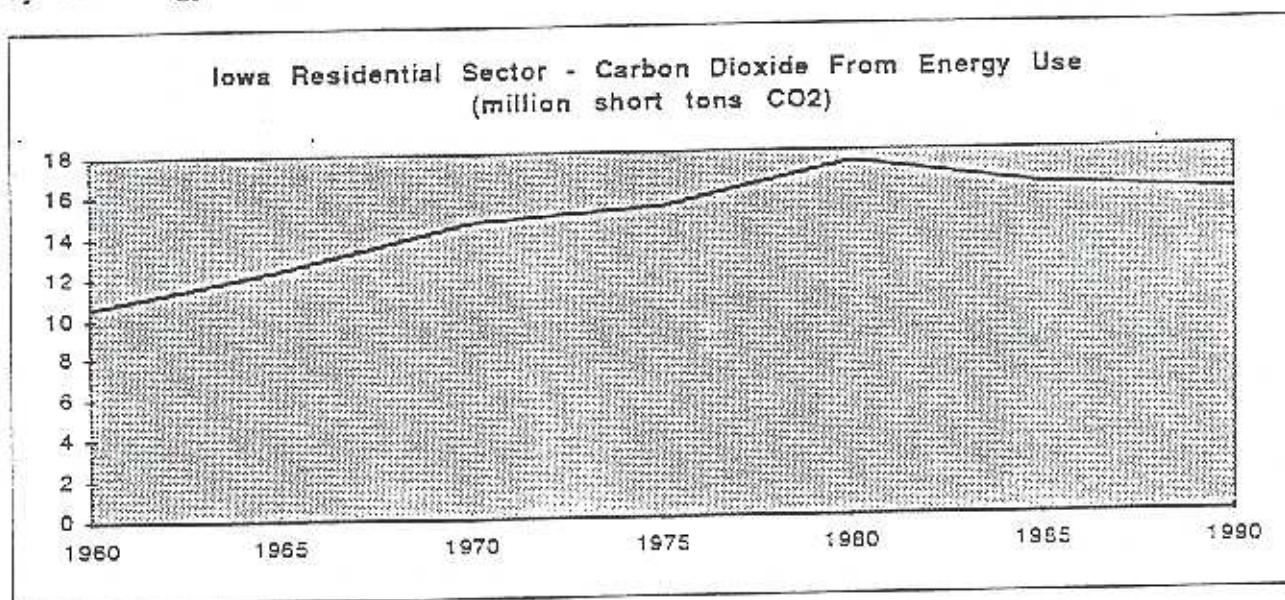
Year	Coal	Natural Gas	Asphalt/ Road Oil	Aviation Gasoline	Distillate Fuel	Jet Fuel	Kerosene	LPG	Lube Oils	Motor Gasoline	Residual Fuel	Other	STATE TOTAL
1960	3.24	2.77	0.00	0.03	1.28	0.02	0.29	0.34	0.04	2.97	0.14	0.01	11.14
1965	3.52	3.08	0.00	0.03	1.27	0.02	0.17	0.50	0.04	3.11	0.07	0.06	12.49
1970	3.80	5.18	0.00	0.02	1.57	0.08	0.05	0.74	0.04	3.60	0.05	0.07	15.22
1971	3.63	5.12	0.00	0.02	1.64	0.07	0.04	0.75	0.04	3.77	0.06	0.10	15.24
1972	4.28	5.12	0.00	0.02	1.72	0.08	0.06	0.84	0.04	3.88	0.07	0.11	16.21
1973	4.33	5.41	0.00	0.01	1.79	0.08	0.06	0.86	0.05	4.25	0.08	0.12	17.02
1974	3.80	5.48	0.00	0.02	1.71	0.08	0.04	0.90	0.04	3.92	0.09	0.12	16.19
1975	3.95	5.13	0.00	0.02	1.67	0.09	0.02	0.92	0.04	3.94	0.08	0.11	15.98
1976	5.12	4.81	0.00	0.02	1.74	0.10	0.02	1.25	0.04	4.11	0.12	0.36	17.50
1977	5.65	4.15	0.00	0.02	1.84	0.11	0.02	1.20	0.04	4.16	0.15	0.43	17.76
1978	6.23	3.53	0.00	0.02	1.95	0.12	0.02	1.06	0.05	4.13	0.12	0.46	17.69
1979	6.99	4.33	0.00	0.02	2.38	0.11	0.05	0.99	0.05	3.89	0.16	0.57	19.54
1980	7.60	4.00	0.00	0.02	1.83	0.09	0.02	0.75	0.04	3.57	0.06	0.50	18.58
1981	8.30	3.75	0.00	0.02	1.67	0.08	0.04	0.67	0.04	3.46	0.01	0.27	18.31
1982	8.03	3.51	0.00	0.01	1.87	0.07	0.05	0.81	0.04	3.33	0.04	0.21	17.97
1983	8.34	3.28	0.00	0.01	1.62	0.06	0.01	0.81	0.04	3.27	0.03	0.18	17.68
1984	8.39	3.48	0.00	0.01	1.77	0.07	0.02	0.49	0.04	3.25	0.02	0.22	17.76
1985	8.83	3.95	0.00	0.01	1.73	0.06	0.02	0.57	0.04	3.18	0.02	0.20	18.07
1986	8.54	3.07	0.00	0.01	1.84	0.06	0.01	0.59	0.04	3.17	0.07	0.12	17.52
1987	9.38	3.01	0.00	0.01	1.81	0.08	0.01	0.41	0.04	3.19	0.02	0.12	18.07
1988	9.93	3.54	0.00	0.01	1.84	0.08	0.01	0.45	0.04	3.29	0.03	0.12	19.33
1989	10.55	3.35	0.00	0.01	1.72	0.08	0.01	0.48	0.04	3.29	0.02	0.12	19.67
1990	11.04	3.23	0.00	0.01	1.75	0.10	0.01	0.43	0.04	3.18	0.02	0.13	19.94
1991	11.54	3.46	0.00	0.01	1.68	0.10	0.01	0.49	0.04	3.20	0.01	0.13	20.74
1992	11.00	3.43	0.00	0.01	1.88	0.09	0.00	0.61	0.04	3.20	0.01	0.14	20.49

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

The high rates of residential energy consumption are also indicated by Iowa's ranking as the 8th most emitting state residential sector per capita.

Residential Sector Trends

Rapid increases in emissions of CO₂ from the residential sector have been slowed since 1980. This is reflective of the surge of new home building, with tighter efficiency standards, as well as the general efficiency improvements brought about by the energy crisis of the 1970s.



Iowa Residential Sector - Carbon Dioxide From Energy Use
(million short tons CO₂)

1960	10.59
1965	12.32
1970	14.59
1975	15.34
1980	17.4
1985	16.24
1990	15.83

Annual Iowa Residential Energy Consumption (Trillion Btu)

Year	Bituminous Coal	Anthracite Coal	Natural Gas	Distillate Fuel	Kerosene	LPG	Electricity	Electrical Losses	STATE TOTAL
1960	8.8	0.0	60.5	15.2	13.0	13.3	12.7	31.6	153.1
1965	3.6	0.0	78.0	13.7	7.5	19.0	17.2	41.1	180.1
1970	1.3	0.0	97.1	13.0	1.8	25.8	22.1	53.6	214.7
1971	0.8	0.0	93.1	11.7	1.4	25.8	23.4	56.5	212.7
1972	0.5	0.0	97.4	13.4	2.0	28.5	24.8	59.8	226.4
1973	0.5	0.0	92.6	12.9	2.1	27.2	26.1	62.5	223.9
1974	0.8	0.0	93.0	11.4	1.2	25.3	26.6	64.9	223.2
1975	0.9	0.0	95.1	10.5	0.8	25.3	28.4	68.6	229.6
1976	0.4	0.0	90.4	10.7	0.7	26.5	28.7	69.2	226.6
1977	0.5	0.0	87.3	11.3	0.8	24.5	30.2	72.9	227.5
1978	1.7	0.0	81.0	12.6	0.8	22.3	32.9	80.4	231.7
1979	2.4	0.0	86.1	19.4	1.4	18.5	33.1	79.9	250.8
1980	0.6	0.0	85.2	13.9	0.3	14.3	34.2	83.3	231.8
1981	1.4	0.0	77.2	11.7	1.3	13.1	33.6	80.1	218.4
1982	1.3	0.1	85.5	12.3	1.7	13.6	34.8	83.6	232.9
1983	1.4	0.0	78.4	5.9	0.3	16.2	37.8	90.4	230.4
1984	1.6	0.0	80.9	6.4	0.8	10.6	33.7	78.4	212.4
1985	2.1	0.0	79.6	8.4	0.7	10.8	33.6	79	214.2
1986	1.9	0.0	74.9	8.1	0.4	11.9	34.1	78.5	209.8
1987	2.4	0.0	65.8	7.1	0.3	9.2	34.3	78.3	197.4
1988	2.7	0.2	76.6	6.5	0.4	11.2	36.4	82.4	216.4
1989	1.4	0.1	78.3	6.2	0.2	12.4	35.5	79.5	213.6
1990	2.0	0.0	71.9	4.8	0.1	9.9	35.9	78.4	202.8
1991	1.9	0.0	79.4	5.2	0.2	12.1	38.1	82.8	219.7
1992	0.5	0.0	75.2	4.5	0.1	12.3	35.1	74.9	202.8

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Residential Sector - Total Carbon Content By Fuel Type (million tons Carbon)

Year	Bituminous Coal	Anthracite Coal	Natural Gas	Distillate Fuel	Kerosene	LPG	Electricity	Electrical System Losses	STATE TOTAL
1960	0.20	0.00	0.96	0.33	0.28	0.25	N/A	N/A	2.03
1965	0.10	0.00	1.24	0.30	0.16	0.36	N/A	N/A	2.17
1970	0.04	0.00	1.55	0.29	0.04	0.49	N/A	N/A	2.40
1971	0.02	0.00	1.46	0.26	0.03	0.49	N/A	N/A	2.28
1972	0.01	0.00	1.55	0.29	0.04	0.54	N/A	N/A	2.44
1973	0.01	0.00	1.48	0.28	0.05	0.51	N/A	N/A	2.34
1974	0.02	0.00	1.48	0.25	0.03	0.48	N/A	N/A	2.28
1975	0.03	0.00	1.52	0.23	0.02	0.48	N/A	N/A	2.27
1976	0.01	0.00	1.44	0.24	0.02	0.50	N/A	N/A	2.20
1977	0.01	0.00	1.39	0.25	0.02	0.48	N/A	N/A	2.14
1978	0.05	0.00	1.29	0.28	0.02	0.42	N/A	N/A	2.06
1979	0.07	0.00	1.53	0.43	0.03	0.35	N/A	N/A	2.41
1980	0.02	0.00	1.36	0.31	0.01	0.27	N/A	N/A	1.96
1981	0.04	0.00	1.23	0.26	0.03	0.25	N/A	N/A	1.81
1982	0.04	0.00	1.36	0.27	0.04	0.26	N/A	N/A	1.97
1983	0.04	0.00	1.25	0.13	0.01	0.31	N/A	N/A	1.73
1984	0.05	0.00	1.29	0.14	0.02	0.20	N/A	N/A	1.70
1985	0.06	0.00	1.27	0.18	0.02	0.20	N/A	N/A	1.73
1986	0.06	0.00	1.19	0.18	0.01	0.22	N/A	N/A	1.66
1987	0.07	0.00	1.05	0.16	0.01	0.17	N/A	N/A	1.46
1988	0.00	0.01	1.22	0.14	0.01	0.21	N/A	N/A	1.67
1989	0.04	0.00	1.25	0.14	0.00	0.23	N/A	N/A	1.67
1990	0.08	0.00	1.15	0.10	0.00	0.19	N/A	N/A	1.50
1991	0.06	0.00	1.27	0.11	0.00	0.23	N/A	N/A	1.67
1992	0.01	0.00	1.20	0.10	0.00	0.23	N/A	N/A	1.55

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Residential Sector - Carbon Available for Combustion (million tons Carbon)

Year	Distillate	Anthracite	Natural Gas	Fuel Oil	Kerosene	LPG	Electricity	Electrical System Losses	STATE TOTAL
1960	0.20	0.00	0.96	0.33	0.28	0.25	N/A	N/A	2.03
1965	0.10	0.00	1.24	0.30	0.16	0.36	N/A	N/A	2.17
1970	0.04	0.00	1.55	0.29	0.04	0.48	N/A	N/A	2.39
1971	0.02	0.00	1.48	0.26	0.03	0.48	N/A	N/A	2.29
1972	0.01	0.00	1.55	0.29	0.04	0.53	N/A	N/A	2.44
1973	0.01	0.00	1.48	0.28	0.05	0.51	N/A	N/A	2.33
1974	0.02	0.00	1.48	0.25	0.03	0.47	N/A	N/A	2.26
1975	0.03	0.00	1.52	0.23	0.02	0.47	N/A	N/A	2.26
1976	0.01	0.00	1.44	0.24	0.02	0.50	N/A	N/A	2.20
1977	0.01	0.00	1.39	0.25	0.02	0.46	N/A	N/A	2.13
1978	0.05	0.00	1.29	0.28	0.02	0.42	N/A	N/A	2.05
1979	0.07	0.00	1.53	0.43	0.03	0.35	N/A	N/A	2.41
1980	0.02	0.00	1.36	0.31	0.01	0.27	N/A	N/A	1.96
1981	0.04	0.00	1.23	0.26	0.03	0.25	N/A	N/A	1.80
1982	0.04	0.00	1.35	0.27	0.04	0.25	N/A	N/A	1.97
1983	0.04	0.00	1.25	0.13	0.01	0.30	N/A	N/A	1.73
1984	0.05	0.00	1.29	0.14	0.02	0.20	N/A	N/A	1.69
1985	0.06	0.00	1.27	0.18	0.02	0.20	N/A	N/A	1.73
1986	0.03	0.00	1.19	0.18	0.01	0.22	N/A	N/A	1.66
1987	0.07	0.00	1.05	0.16	0.01	0.17	N/A	N/A	1.45
1988	0.08	0.01	1.22	0.14	0.01	0.21	N/A	N/A	1.67
1989	0.04	0.00	1.25	0.14	0.00	0.23	N/A	N/A	1.67
1990	0.06	0.00	1.15	0.10	0.00	0.19	N/A	N/A	1.49
1991	0.08	0.00	1.27	0.11	0.00	0.23	N/A	N/A	1.67
1992	0.01	0.00	1.20	0.10	0.00	0.23	N/A	N/A	1.55

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Residential Sector - Carbon Oxidized From Energy Uses
(million tons Carbon)

Year	Bituminous Coal	Anthracite Coal	Natural Gas	Distillate Fuel	Kerosene	LPG	Electricity	Electrical System Losses	STATE TOTAL
1960	0.19	0.00	0.00	0.33	0.28	0.25	0.25	0.63	2.89
1965	0.10	0.00	1.21	0.30	0.10	0.35	0.36	0.85	3.30
1970	0.04	0.00	1.54	0.28	0.04	0.48	0.47	1.13	3.03
1971	0.02	0.00	1.48	0.25	0.03	0.48	0.51	1.22	3.99
1972	0.01	0.00	1.55	0.29	0.04	0.63	0.56	1.35	4.33
1973	0.01	0.00	1.47	0.28	0.05	0.50	0.59	1.42	4.33
1974	0.02	0.00	1.40	0.25	0.03	0.47	0.55	1.33	4.12
1975	0.03	0.00	1.51	0.23	0.02	0.47	0.57	1.37	4.18
1976	0.01	0.00	1.43	0.23	0.02	0.49	0.63	1.52	4.33
1977	0.01	0.00	1.39	0.25	0.02	0.45	0.67	1.63	4.42
1978	0.05	0.00	1.29	0.27	0.02	0.41	0.81	1.99	4.84
1979	0.07	0.00	1.53	0.42	0.03	0.34	0.76	1.84	4.99
1980	0.02	0.00	1.35	0.30	0.01	0.26	0.82	1.99	4.74
1981	0.04	0.00	1.23	0.25	0.03	0.24	0.83	1.97	4.58
1982	0.04	0.00	1.38	0.27	0.04	0.25	0.85	2.04	4.05
1983	0.04	0.00	1.24	0.13	0.01	0.30	0.93	2.22	4.06
1984	0.05	0.00	1.28	0.14	0.02	0.20	0.81	1.89	4.39
1985	0.03	0.00	1.26	0.18	0.02	0.20	0.81	1.90	4.43
1986	0.05	0.00	1.19	0.18	0.01	0.22	0.82	1.88	4.35
1987	0.07	0.00	1.04	0.15	0.01	0.17	0.84	1.93	4.21
1988	0.08	0.01	1.22	0.14	0.01	0.21	0.89	2.02	4.58
1989	0.04	0.00	1.24	0.14	0.00	0.23	0.88	1.96	4.50
1990	0.08	0.00	1.14	0.10	0.00	0.18	0.89	1.94	4.32
1991	0.05	0.00	1.26	0.11	0.00	0.22	0.91	1.98	4.55
1992	0.01	0.00	1.19	0.10	0.00	0.23	0.85	1.83	4.22

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Residential Sector - Carbon Dioxide From Energy Uses (million tons CO2)

Year	Bituminous Coal	Anthracite Coal	Natural Gas	Distillate Fuel	Kerosene	LPG	Electricity	Electrical System Losses	STATE TOTAL
1960	0.71	0.00	3.52	1.21	1.03	0.90	0.92	2.29	10.59
1965	0.38	0.00	4.54	1.09	0.59	1.29	1.31	3.12	12.32
1970	0.14	0.00	5.65	1.04	0.14	1.75	1.71	4.15	14.59
1971	0.08	0.00	5.42	0.93	0.11	1.75	1.86	4.48	14.64
1972	0.05	0.00	5.57	1.07	0.16	1.94	2.05	4.95	15.89
1973	0.05	0.00	5.39	1.03	0.17	1.85	2.18	5.22	15.89
1974	0.08	0.00	5.41	0.91	0.09	1.72	2.00	4.89	15.11
1975	0.09	0.00	5.53	0.84	0.06	1.72	2.08	5.01	15.34
1976	0.04	0.00	5.26	0.85	0.06	1.80	2.31	5.56	15.98
1977	0.05	0.00	5.08	0.90	0.08	1.66	2.47	5.96	16.19
1978	0.18	0.00	4.71	1.01	0.06	1.51	2.98	7.29	17.75
1979	0.25	0.00	5.59	1.55	0.11	1.28	2.79	6.74	18.29
1980	0.06	0.00	4.96	1.11	0.02	0.97	2.99	7.28	17.40
1981	0.15	0.00	4.49	0.93	0.10	0.89	3.03	7.21	16.81
1982	0.14	0.01	4.98	0.98	0.13	0.92	3.12	7.50	17.78
1983	0.15	0.00	4.56	0.47	0.02	1.10	3.40	8.13	17.84
1984	0.17	0.00	4.71	0.51	0.06	0.72	2.98	6.93	16.08
1985	0.22	0.00	4.63	0.67	0.08	0.73	2.95	6.97	16.24
1986	0.20	0.00	4.36	0.65	0.03	0.81	3.00	6.90	15.94
1987	0.25	0.00	3.03	0.57	0.02	0.62	3.09	7.05	15.45
1988	0.28	0.02	4.16	0.52	0.03	0.76	3.27	7.40	16.74
1989	0.15	0.01	4.56	0.50	0.02	0.84	3.22	7.20	16.49
1990	0.21	0.00	4.18	0.37	0.01	0.67	3.28	7.12	15.83
1991	0.20	0.00	4.62	0.42	0.02	0.82	3.35	7.28	16.70
1992	0.05	0.00	4.38	0.36	0.01	0.84	3.14	6.70	15.48

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

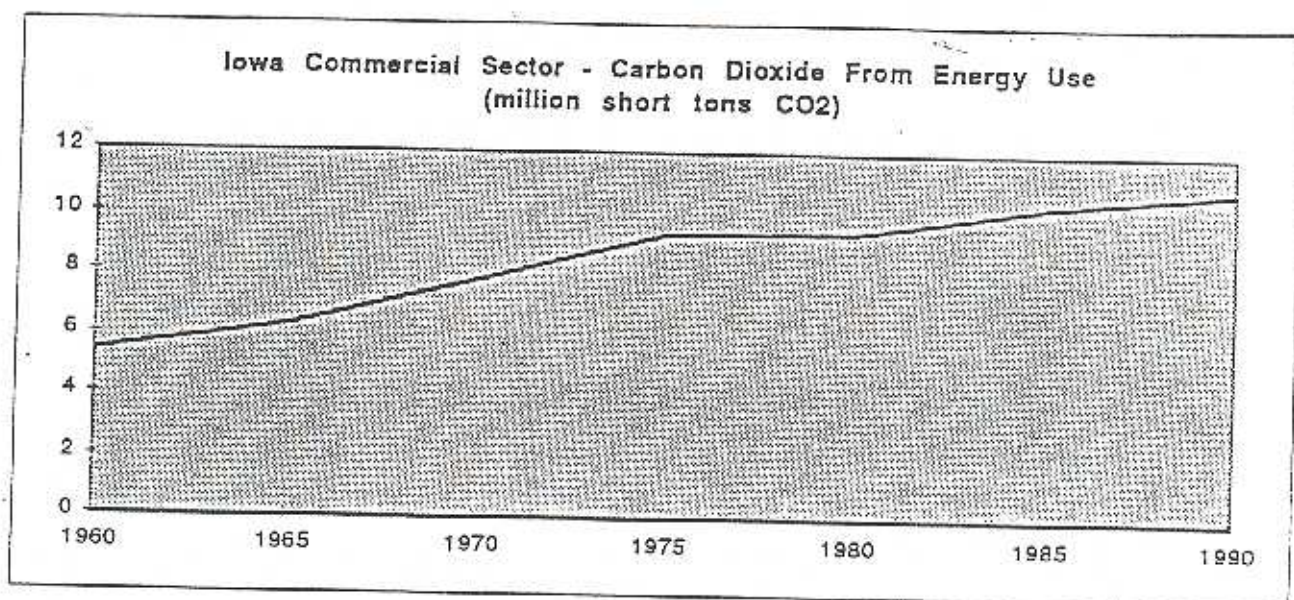
Iowa Residential Sector - Carbon Oxidized From Energy Uses (million metric tons Carbon)

Year	Bituminous Coal	Anthracite Coal	Natural Gas	Fuel Oil	Kerosene	LPG	Electricity	System Losses	STATE TOTAL
1960	0.18	0.00	0.87	0.30	0.25	0.22	0.23	0.57	2.62
1965	0.09	0.00	1.12	0.27	0.15	0.32	0.32	0.77	3.05
1970	0.03	0.00	1.40	0.26	0.04	0.43	0.42	1.03	3.61
1971	0.02	0.00	1.34	0.23	0.03	0.43	0.46	1.11	3.62
1972	0.01	0.00	1.40	0.28	0.04	0.48	0.51	1.23	3.93
1973	0.01	0.00	1.33	0.25	0.04	0.48	0.54	1.29	3.93
1974	0.02	0.00	1.34	0.23	0.02	0.43	0.50	1.21	3.74
1975	0.02	0.00	1.37	0.21	0.02	0.43	0.51	1.24	3.80
1976	0.01	0.00	1.30	0.21	0.01	0.45	0.57	1.38	3.93
1977	0.01	0.00	1.26	0.22	0.02	0.41	0.61	1.47	4.01
1978	0.04	0.00	1.17	0.25	0.02	0.37	0.74	1.80	4.39
1979	0.06	0.00	1.38	0.38	0.03	0.31	0.69	1.67	4.53
1980	0.02	0.00	1.23	0.27	0.01	0.24	0.74	1.80	4.30
1981	0.04	0.00	1.11	0.23	0.03	0.22	0.75	1.78	4.16
1982	0.03	0.00	1.23	0.24	0.03	0.23	0.77	1.86	4.40
1983	0.04	0.00	1.13	0.12	0.01	0.27	0.84	2.01	4.41
1984	0.04	0.00	1.16	0.13	0.02	0.18	0.74	1.71	3.98
1985	0.05	0.00	1.15	0.17	0.01	0.18	0.73	1.72	4.02
1986	0.05	0.00	1.08	0.16	0.01	0.20	0.74	1.71	3.94
1987	0.06	0.00	0.95	0.14	0.01	0.15	0.77	1.75	3.82
1988	0.07	0.01	1.10	0.13	0.01	0.19	0.81	1.83	4.14
1989	0.04	0.00	1.13	0.12	0.00	0.21	0.80	1.78	4.08
1990	0.05	0.00	1.04	0.09	0.00	0.17	0.81	1.76	3.92
1991	0.05	0.00	1.14	0.10	0.00	0.20	0.83	1.80	4.13
1992	0.01	0.00	1.08	0.09	0.00	0.21	0.78	1.66	3.83

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Commercial Sector Trends

The commercial sector has shown steady growth in CO₂ emissions since 1960, but remains the smallest of Iowa's economic sectors.



Iowa Commercial Sector - Carbon Dioxide From Energy Use
(million short tons CO₂)

1960	5.45
1965	6.28
1970	7.8
1975	9.29
1980	9.41
1985	10.3
1990	10.85

Annual Iowa Commercial Energy Consumption (Trillion Btu)

Year	Bitum. Coal	Anthracite Coal	Natural Gas	Distillate Fuel	Kerosene	LPG	Motor Gasoline	Residual Fuel	Electricity	Electrical System Losses	STATE TOTAL
1960	12.6	0.0	28.8	6.1	0.5	2.3	0.9	1.5	6.2	15.4	74.3
1965	6.7	0.0	39.1	5.5	0.3	3.4	1.0	0.9	9.5	22.8	89.2
1970	2.4	0.0	57.8	5.2	0.1	4.6	1.4	0.4	12.5	30.2	114.6
1971	1.6	0.0	59.7	4.7	0.1	4.6	1.4	0.5	13.3	32.3	118.2
1972	1.0	0.0	62.2	5.4	0.1	5.0	1.5	0.5	14.2	34.3	124.2
1973	1.0	0.0	64.2	5.2	0.1	4.8	1.6	0.8	15.0	36.0	128.7
1974	1.5	0.0	64.8	4.6	0.0	4.5	1.6	1.1	15.3	37.4	130.8
1975	1.6	0.0	67.5	4.2	0.0	4.5	1.7	0.7	17.5	42.1	139.8
1976	0.7	0.0	65.2	4.3	0.0	4.7	4.4	1.0	18.1	43.6	141.9
1977	1.0	0.0	60.7	4.5	0.0	4.3	6.2	1.3	18.7	45.1	141.8
1978	3.2	0.0	49.3	5.0	0.0	3.9	6.3	1.0	19.5	47.7	135.9
1979	4.4	0.0	58.4	7.8	0.1	3.3	6.7	1.5	20.0	48.2	150.4
1980	1.2	0.0	50.7	4.4	0.0	2.5	1.8	0.5	18.8	45.6	125.5
1981	2.8	0.0	46.9	3.6	0.1	2.3	2.0	0.2	23.1	55.1	135.9
1982	2.3	0.0	51.9	3.8	0.2	2.4	2.0	0.2	23.4	56.1	142.3
1983	2.7	0.0	47.5	7.1	0.0	2.9	1.3	0.0	24.5	56.7	144.7
1984	2.9	0.0	46.8	7.7	0.0	1.9	1.1	0.0	21.4	49.9	133.7
1985	3.8	0.0	48.2	6.6	0.0	1.9	1.2	0.0	21.5	50.6	133.7
1986	3.5	0.0	44.1	4.0	0.0	2.1	1.4	0.2	22.4	51.4	129.1
1987	4.5	0.0	38.4	4.4	0.0	1.6	1.4	0.1	22.9	52.4	125.7
1988	4.9	0.2	45.3	4.0	0.0	2.0	1.8	0.1	24.3	55.0	137.6
1989	2.6	0.0	46.7	2.9	0.0	2.2	1.2	0.2	24.9	55.9	136.5
1990	3.8	0.0	44.3	2.9	0.2	1.8	0.7	0.2	25.7	56.1	135.7
1991	3.5	0.0	47.0	3.3	0.0	2.1	3.8	0.1	27.1	58.9	145.8
1992	0.9	0.0	46.3	2.8	0.0	2.2	3.4	0.2	26.6	56.7	139.1

Iowa Energy Consumption Data From Energy Information Administration, 'State Energy Data Report'

Iowa Commercial Sector - Total Carbon Content By Fuel Type (million tons Carbon)

Year	Bitum. Coal	Anthracite Coal	Natural Gas	Distillate Fuel	Kerosene	LPG	Motor Gasoline	Residual Fuel	Electricity	Electrical System Losses	STATE TOTAL
1960	0.38	0.00	0.46	0.13	0.01	0.04	0.02	0.04	N/A	N/A	1.07
1965	0.19	0.00	0.62	0.12	0.01	0.06	0.02	0.02	N/A	N/A	1.05
1970	0.07	0.00	0.92	0.11	0.00	0.09	0.03	0.01	N/A	N/A	1.23
1971	0.05	0.00	0.95	0.10	0.00	0.09	0.03	0.01	N/A	N/A	1.23
1972	0.03	0.00	0.99	0.12	0.00	0.09	0.03	0.01	N/A	N/A	1.28
1973	0.03	0.00	1.02	0.11	0.00	0.09	0.03	0.02	N/A	N/A	1.31
1974	0.04	0.00	1.03	0.10	0.00	0.09	0.03	0.03	N/A	N/A	1.32
1975	0.05	0.00	1.08	0.09	0.00	0.09	0.04	0.02	N/A	N/A	1.35
1976	0.02	0.00	1.04	0.09	0.00	0.09	0.09	0.02	N/A	N/A	1.36
1977	0.03	0.00	0.97	0.10	0.00	0.06	0.13	0.03	N/A	N/A	1.34
1978	0.09	0.00	0.79	0.11	0.00	0.07	0.13	0.02	N/A	N/A	1.22
1979	0.13	0.00	0.93	0.17	0.00	0.06	0.14	0.04	N/A	N/A	1.47
1980	0.03	0.00	0.81	0.10	0.00	0.05	0.04	0.01	N/A	N/A	1.04
1981	0.08	0.00	0.75	0.08	0.00	0.04	0.04	0.00	N/A	N/A	1.00
1982	0.07	0.00	0.83	0.08	0.00	0.05	0.04	0.00	N/A	N/A	1.08
1983	0.03	0.00	0.76	0.10	0.00	0.05	0.03	0.00	N/A	N/A	1.07
1984	0.08	0.00	0.78	0.17	0.00	0.04	0.02	0.00	N/A	N/A	1.09
1985	0.11	0.00	0.77	0.14	0.00	0.04	0.03	0.00	N/A	N/A	1.03
1986	0.10	0.00	0.70	0.09	0.00	0.04	0.03	0.00	N/A	N/A	0.97
1987	0.13	0.00	0.61	0.10	0.00	0.03	0.03	0.00	N/A	N/A	0.90
1988	0.14	0.01	0.72	0.09	0.00	0.04	0.04	0.00	N/A	N/A	1.04
1989	0.07	0.00	0.74	0.06	0.00	0.04	0.03	0.00	N/A	N/A	0.95
1990	0.11	0.00	0.71	0.06	0.00	0.03	0.01	0.00	N/A	N/A	0.94
1991	0.10	0.00	0.75	0.07	0.00	0.04	0.08	0.00	N/A	N/A	1.05
1992	0.03	0.00	0.74	0.06	0.00	0.04	0.07	0.00	N/A	N/A	0.95

Iowa Energy Consumption Data From Energy Information Administration, 'State Energy Data Report'

Iowa Commercial Sector - Carbon Available for Combustion By Fuel Type
(million tons Carbon)

Year	Bltum. Coal	Anthrachte Coal	Natural Gas	Distillate Fuel	Kerosene	LPG	Motor Gasoline	Residual Fuel	Electricity	Electrical System Losses	STATE TOTAL
1960	0.36	0.00	0.45	0.13	0.01	0.04	0.02	0.04	N/A	N/A	1.07
1965	0.19	0.00	0.62	0.12	0.01	0.06	0.02	0.02	N/A	N/A	1.05
1970	0.07	0.00	0.92	0.11	0.00	0.09	0.03	0.01	N/A	N/A	1.23
1971	0.05	0.00	0.95	0.10	0.00	0.09	0.03	0.01	N/A	N/A	1.23
1972	0.03	0.00	0.98	0.12	0.00	0.09	0.03	0.01	N/A	N/A	1.26
1973	0.03	0.00	1.02	0.11	0.00	0.09	0.03	0.02	N/A	N/A	1.31
1974	0.04	0.00	1.03	0.10	0.00	0.08	0.03	0.03	N/A	N/A	1.32
1975	0.05	0.00	1.06	0.09	0.00	0.08	0.04	0.02	N/A	N/A	1.35
1976	0.02	0.00	1.04	0.09	0.00	0.09	0.03	0.02	N/A	N/A	1.36
1977	0.03	0.00	0.97	0.10	0.00	0.08	0.13	0.03	N/A	N/A	1.34
1978	0.09	0.00	0.79	0.11	0.00	0.07	0.13	0.02	N/A	N/A	1.22
1979	0.13	0.00	0.93	0.17	0.00	0.06	0.14	0.04	N/A	N/A	1.47
1980	0.03	0.00	0.81	0.10	0.00	0.05	0.04	0.01	N/A	N/A	1.04
1981	0.03	0.00	0.75	0.08	0.00	0.04	0.04	0.00	N/A	N/A	1.00
1982	0.07	0.00	0.83	0.08	0.00	0.04	0.04	0.00	N/A	N/A	1.07
1983	0.09	0.00	0.76	0.16	0.00	0.05	0.03	0.00	N/A	N/A	1.07
1984	0.09	0.00	0.78	0.17	0.00	0.04	0.02	0.00	N/A	N/A	1.09
1985	0.11	0.00	0.77	0.14	0.00	0.04	0.03	0.00	N/A	N/A	1.08
1986	0.10	0.00	0.70	0.09	0.00	0.04	0.03	0.00	N/A	N/A	0.97
1987	0.13	0.00	0.61	0.10	0.00	0.03	0.03	0.00	N/A	N/A	0.90
1988	0.14	0.01	0.72	0.09	0.00	0.04	0.04	0.00	N/A	N/A	1.04
1989	0.07	0.00	0.74	0.06	0.00	0.04	0.03	0.00	N/A	N/A	0.95
1990	0.11	0.00	0.71	0.06	0.00	0.03	0.01	0.00	N/A	N/A	0.94
1991	0.10	0.00	0.75	0.07	0.00	0.04	0.06	0.00	N/A	N/A	1.05
1992	0.03	0.00	0.74	0.05	0.00	0.04	0.07	0.00	N/A	N/A	0.94

Iowa Energy Consumption Data From Energy Information Administration, "State Energy Data Report"

Iowa Commercial Sector - Carbon Oxidized From Energy Uses (million tons Carbon)

Year	Bitum. Coal	Anthracite Coal	Natural Gas	Distillate Fuel	Kerosene	LPG	Motor Gasoline	Residual Fuel	Electricity	Electrical System Losses	STATE TOTAL
1960	0.36	0.00	0.46	0.13	0.01	0.04	0.02	0.04	0.12	0.30	1.49
1965	0.19	0.00	0.62	0.12	0.01	0.06	0.02	0.02	0.20	0.47	1.71
1970	0.07	0.00	0.92	0.11	0.00	0.09	0.03	0.01	0.26	0.64	2.13
1971	0.05	0.00	0.95	0.10	0.00	0.09	0.03	0.01	0.29	0.70	2.21
1972	0.03	0.00	0.99	0.12	0.00	0.09	0.03	0.01	0.32	0.78	2.37
1973	0.03	0.00	1.02	0.11	0.00	0.09	0.03	0.02	0.34	0.82	2.47
1974	0.04	0.00	1.03	0.10	0.00	0.08	0.04	0.02	0.35	0.77	2.40
1975	0.05	0.00	1.07	0.09	0.00	0.08	0.04	0.02	0.40	0.84	2.53
1976	0.02	0.00	1.03	0.09	0.00	0.09	0.09	0.02	0.42	0.95	2.70
1977	0.03	0.00	0.96	0.10	0.00	0.08	0.13	0.03	0.48	1.01	2.75
1978	0.09	0.00	0.78	0.11	0.00	0.07	0.13	0.02	0.46	1.11	3.03
1979	0.13	0.00	0.93	0.17	0.00	0.06	0.14	0.04	0.45	1.09	2.57
1980	0.03	0.00	0.80	0.10	0.00	0.05	0.04	0.00	0.57	1.35	2.91
1981	0.07	0.00	0.74	0.09	0.00	0.04	0.04	0.00	0.57	1.37	3.01
1982	0.07	0.00	0.92	0.08	0.00	0.04	0.04	0.00	0.60	1.44	3.11
1983	0.08	0.00	0.75	0.15	0.00	0.05	0.03	0.00	0.52	1.20	2.80
1984	0.00	0.00	0.77	0.17	0.00	0.04	0.02	0.00	0.52	1.22	2.81
1985	0.11	0.00	0.78	0.14	0.00	0.04	0.03	0.00	0.54	1.23	2.73
1986	0.10	0.00	0.70	0.09	0.00	0.04	0.03	0.00	0.56	1.29	2.75
1987	0.13	0.00	0.61	0.10	0.00	0.03	0.03	0.00	0.59	1.35	2.97
1988	0.14	0.01	0.72	0.09	0.00	0.04	0.04	0.00	0.62	1.38	2.94
1989	0.07	0.00	0.74	0.05	0.00	0.04	0.03	0.00	0.64	1.30	2.96
1990	0.11	0.00	0.70	0.06	0.00	0.03	0.01	0.00	0.85	1.41	3.10
1991	0.10	0.00	0.75	0.07	0.00	0.04	0.08	0.00	0.65	1.38	2.97
1992	0.03	0.00	0.73	0.06	0.00	0.04	0.07	0.00			

Iowa Energy Consumption Data From Energy Information Administration, "State Energy Data Report"

Iowa Commercial Sector - Carbon Dioxide Emissions From Energy Uses (million tons CO₂)

Year	Bitum. Coal	Anthracite Coal	Natural Gas	Distillate Fuel	Kerosene	LPG	Motor Gasoline	Residual Fuel	Electricity	Electrical System Losses	STATE TOTAL
1960	1.32	0.00	1.60	0.49	0.04	0.16	0.07	0.13	0.45	1.12	5.45
1965	0.70	0.00	2.28	0.44	0.02	0.23	0.08	0.08	0.72	1.73	6.28
1970	0.25	0.00	3.36	0.42	0.01	0.31	0.11	0.03	0.97	2.34	7.80
1971	0.17	0.00	3.47	0.30	0.01	0.31	0.11	0.04	1.05	2.58	8.11
1972	0.11	0.00	3.62	0.43	0.01	0.34	0.12	0.04	1.18	2.84	8.68
1973	0.11	0.00	3.74	0.42	0.01	0.33	0.12	0.07	1.25	3.01	9.04
1974	0.16	0.00	3.77	0.37	0.00	0.31	0.12	0.09	1.15	2.82	8.79
1975	0.17	0.00	3.93	0.34	0.00	0.31	0.13	0.06	1.28	3.00	9.29
1976	0.07	0.00	3.79	0.34	0.00	0.32	0.34	0.09	1.46	3.50	9.91
1977	0.11	0.00	3.53	0.36	0.00	0.29	0.48	0.11	1.53	3.69	10.10
1978	0.34	0.00	2.87	0.40	0.00	0.26	0.49	0.09	1.77	4.32	10.54
1979	0.46	0.00	3.40	0.62	0.01	0.22	0.52	0.13	1.69	4.07	11.12
1980	0.13	0.00	2.95	0.35	0.00	0.17	0.14	0.04	1.64	3.99	9.41
1981	0.27	0.00	2.73	0.20	0.01	0.16	0.16	0.02	2.08	4.96	10.67
1982	0.24	0.00	3.02	0.30	0.02	0.16	0.16	0.02	2.10	5.03	11.05
1983	0.28	0.00	2.76	0.57	0.00	0.20	0.10	0.00	2.20	5.28	11.40
1984	0.30	0.00	2.84	0.61	0.00	0.13	0.09	0.00	1.89	4.41	10.28
1985	0.40	0.00	2.80	0.52	0.00	0.13	0.09	0.00	1.90	4.46	10.30
1986	0.37	0.00	2.57	0.32	0.00	0.14	0.11	0.02	1.97	4.52	10.01
1987	0.47	0.00	2.23	0.35	0.00	0.11	0.11	0.01	2.07	4.73	10.08
1988	0.51	0.02	2.64	0.32	0.00	0.14	0.14	0.01	2.18	4.94	10.89
1989	0.25	0.00	2.72	0.23	0.00	0.15	0.09	0.02	2.26	5.08	10.79
1990	0.40	0.00	2.58	0.23	0.02	0.12	0.05	0.02	2.34	5.10	10.85
1991	0.37	0.00	2.73	0.26	0.00	0.14	0.30	0.01	2.38	5.18	11.37
1992	0.09	0.00	2.69	0.22	0.00	0.15	0.26	0.02	2.38	5.07	10.90

Iowa Energy Consumption Data From Energy Information Administration, 'State Energy Data Report'

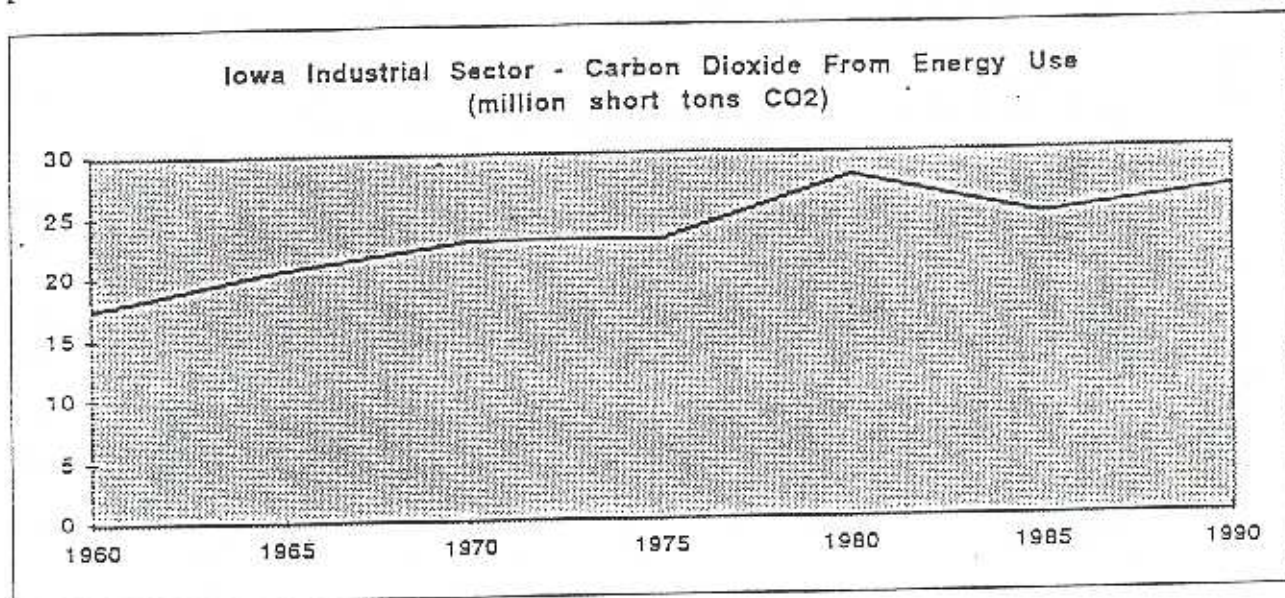
Iowa Commercial Sector - Carbon Oxidized From Energy Uses
(million metric tons Carbon)

Year	Bituminous Coal	Anthracite Coal	Natural Gas	Distillate Fuel	Kerosene	LPG	Motor Gasoline	Residual Fuel	Electricity	Electrical System Losses	STATE TOTAL
1960	0.33	0.00	0.41	0.12	0.01	0.04	0.02	0.03	0.11	0.28	1.35
1965	0.17	0.00	0.56	0.11	0.01	0.03	0.02	0.02	0.19	0.43	1.55
1970	0.09	0.00	0.83	0.10	0.00	0.08	0.03	0.01	0.24	0.58	1.93
1971	0.04	0.00	0.88	0.09	0.00	0.08	0.03	0.01	0.26	0.63	2.01
1972	0.03	0.00	0.90	0.11	0.00	0.08	0.03	0.01	0.29	0.70	2.15
1973	0.03	0.00	0.92	0.10	0.00	0.08	0.03	0.02	0.31	0.74	2.24
1974	0.04	0.00	0.93	0.09	0.00	0.08	0.03	0.02	0.28	0.70	2.17
1975	0.04	0.00	0.97	0.08	0.00	0.08	0.03	0.01	0.32	0.76	2.30
1976	0.02	0.00	0.94	0.08	0.00	0.08	0.08	0.02	0.36	0.87	2.45
1977	0.03	0.00	0.87	0.09	0.00	0.07	0.12	0.03	0.38	0.91	2.50
1978	0.08	0.00	0.71	0.10	0.00	0.07	0.12	0.02	0.44	1.07	2.61
1979	0.11	0.00	0.84	0.15	0.00	0.06	0.13	0.03	0.42	1.01	2.75
1980	0.03	0.00	0.73	0.09	0.00	0.04	0.03	0.01	0.41	0.99	2.33
1981	0.07	0.00	0.60	0.07	0.00	0.04	0.04	0.00	0.51	1.23	2.64
1982	0.06	0.00	0.75	0.00	0.00	0.04	0.04	0.00	0.52	1.24	2.73
1983	0.07	0.00	0.68	0.14	0.00	0.05	0.02	0.00	0.55	1.31	2.82
1984	0.09	0.00	0.70	0.15	0.00	0.03	0.02	0.00	0.47	1.09	2.54
1985	0.10	0.00	0.69	0.13	0.00	0.03	0.02	0.00	0.47	1.10	2.55
1986	0.09	0.00	0.63	0.08	0.00	0.04	0.03	0.00	0.49	1.12	2.48
1987	0.12	0.00	0.55	0.09	0.00	0.03	0.03	0.00	0.51	1.17	2.49
1988	0.13	0.01	0.65	0.08	0.00	0.03	0.03	0.00	0.54	1.22	2.70
1989	0.07	0.00	0.67	0.06	0.00	0.04	0.02	0.00	0.56	1.25	2.67
1990	0.10	0.00	0.64	0.06	0.00	0.03	0.01	0.00	0.56	1.26	2.68
1991	0.09	0.00	0.68	0.07	0.00	0.04	0.07	0.00	0.58	1.29	2.81
1992	0.02	0.00	0.67	0.06	0.00	0.04	0.07	0.00	0.59	1.26	2.70

Iowa Energy Consumption Data From Energy Information Administration, 'State Energy Data Report'

Industrial Sector Trends

The industrial sector continues to be the largest emitter of Iowa's economic sectors. This is due to high energy demands of industrial processes, and the relative inefficiency of many of Iowa's older facilities. However, efficiency has been gained in this sector as demonstrated by the decrease in emissions of CO₂ per gross state product.



Iowa Industrial Sector - Carbon Dioxide From Energy Use
(million short tons CO₂)

1960	17.47
1965	20.57
1970	22.96
1975	22.79
1980	27.97
1985	24.59
1990	26.67

Annual Iowa Industrial Energy Consumption (Trillion Btu)

Year	Bitum. Coal	Anthr. Coal	Natural Gas	Asphalt/ Road Oil	Distillate Fuel	Kerosene	LPG	Lubes	Motor Resid Gas	Fuel Oil	Other	Elec Losses	STATE TOTAL
1960	48.4	3.2	44.9	17.1	32.2	1.1	4.4	1.2	30.5	3.6	0.2	9.1	218.6
1965	54.6	2.9	60.9	17.0	32.7	0.8	7.3	1.3	28.2	2.2	2.9	12.7	261.8
1970	41.5	1.4	99.9	19.3	34.3	0.9	11.1	1.3	28.3	1.6	3.3	18.2	305.2
1971	30.6	1.1	103.0	20.7	33.7	0.7	11.4	1.1	23.1	1.4	4.8	19.3	297.6
1972	33.6	0.7	106.5	19.7	32.3	0.8	13.3	1.2	22.8	1.1	5.3	21.7	311.2
1973	33.9	0.6	133.4	17.3	32.8	0.9	15.3	1.5	25.7	1.9	5.8	24.0	350.6
1974	28.0	0.7	134.8	17.0	29.6	0.8	19.9	1.4	20.1	2.5	5.9	24.6	345.2
1975	27.5	0.9	122.5	15.2	27.2	0.4	20.8	0.9	19.9	1.8	5.4	22.6	319.6
1976	31.7	1.0	123.3	16.2	26.7	0.5	37.7	1.0	14.8	2.4	17.3	25.1	359.0
1977	30.8	0.9	112.6	16.9	27.8	0.4	36.6	1.2	12.7	3.4	21.0	27.4	357.9
1978	29.0	0.7	95.2	18.9	31.2	0.4	31.1	1.2	10.0	2.4	22.8	29.4	344.1
1979	35.6	0.5	110.4	20.9	39.2	1.2	32.1	1.3	9.1	4.1	27.3	30.2	392.9
1980	31.6	0.8	114.9	11.3	27.4	0.7	24.1	1.2	13.7	1.7	28.7	31.8	365.2
1981	30.9	1.1	115.5	13.1	25.1	0.7	20.2	1.1	15.2	0.4	13.0	33.3	348.9
1982	30.8	0.4	90.1	12.7	26.7	0.7	26.8	1.0	11.4	1.8	10.1	31.8	320.7
1983	31.2	0.4	86.3	10.6	22.2	0.2	24.0	1.1	4.9	1.2	9.0	32.4	301.2
1984	31.7	0.6	94.7	12.2	24.0	0.2	13.4	1.1	9.1	0.0	10.1	32.5	306.1
1985	35.2	0.4	88.0	13.4	27.9	0.2	17.6	1.1	8.9	1.1	9.6	32.5	312.2
1986	35.1	0.4	81.2	13.5	34.1	0.2	17.4	1.0	7.9	3.0	5.6	33.4	309.7
1987	41.9	0.6	99.1	11.9	28.9	0.3	11.3	1.2	7.8	0.6	5.7	35.0	314.3
1988	41.2	0.5	102.7	14.7	29.9	0.1	10.8	1.1	7.4	1.5	5.6	37.6	338.1
1989	53.4	0.5	90.3	11.3	23.9	0.1	11.6	1.2	6.8	0.9	5.5	37.6	327.4
1990	52.4	0.7	90.9	10.2	24.1	0.1	11.2	1.2	5.6	0.6	6.1	30.9	326.9
1991	58.9	0.4	98.2	10.4	26.8	0.1	11.8	1.1	6.1	0.5	6.2	39.9	347.0
1992	52.7	0.2	101.2	9.3	26.2	0.1	17.9	1.1	5.5	0.4	6.5	41.4	360.8

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Industrial Sector - Total Carbon Content By Fuel Type (million tons Carbon)

Year	Dilum. Anthr. Coal		Natural Gas	Asphalt/ Road Oil	Distillate Fuel	Kerosene	LPG	Motor Reald			Elec	Elec	STATE
	Coal	Coal						Lubes	Gas	Fuel	Other	Losses	TOTAL
1960	1.40	0.10	0.72	0.39	0.71	0.02	0.08	0.02	0.65	0.08	0.00	N/A	4.19
1965	1.58	0.09	1.10	0.39	0.72	0.02	0.14	0.02	0.60	0.05	0.06	N/A	4.77
1970	1.20	0.04	1.59	0.44	0.75	0.02	0.21	0.02	0.61	0.04	0.07	N/A	5.00
1971	0.89	0.03	1.64	0.47	0.74	0.02	0.22	0.02	0.49	0.03	0.11	N/A	4.68
1972	0.97	0.02	1.70	0.45	0.71	0.02	0.25	0.02	0.49	0.03	0.12	N/A	4.77
1973	0.98	0.02	2.13	0.39	0.72	0.02	0.29	0.03	0.55	0.04	0.13	N/A	5.30
1974	0.81	0.02	2.15	0.39	0.65	0.02	0.38	0.03	0.43	0.08	0.13	N/A	5.06
1975	0.80	0.03	1.95	0.35	0.60	0.01	0.39	0.02	0.43	0.04	0.12	N/A	4.73
1976	0.92	0.03	1.97	0.37	0.59	0.01	0.71	0.02	0.31	0.06	0.38	N/A	5.36
1977	0.89	0.03	1.80	0.38	0.61	0.01	0.69	0.02	0.27	0.08	0.45	N/A	5.25
1978	0.84	0.02	1.52	0.43	0.69	0.01	0.59	0.02	0.21	0.06	0.50	N/A	4.89
1979	1.03	0.02	1.83	0.43	0.86	0.03	0.61	0.02	0.19	0.10	0.60	N/A	5.82
1980	0.91	0.02	1.83	0.26	0.60	0.02	0.46	0.02	0.33	0.04	0.63	N/A	5.09
1981	0.89	0.03	1.84	0.30	0.55	0.02	0.38	0.02	0.33	0.01	0.29	N/A	4.68
1982	0.89	0.01	1.44	0.29	0.59	0.02	0.51	0.02	0.24	0.04	0.22	N/A	4.27
1983	0.90	0.01	1.38	0.24	0.49	0.00	0.45	0.02	0.10	0.03	0.20	N/A	3.83
1984	0.92	0.02	1.51	0.28	0.53	0.00	0.25	0.02	0.19	0.02	0.22	N/A	3.97
1985	1.02	0.01	1.40	0.30	0.61	0.00	0.33	0.02	0.19	0.03	0.21	N/A	4.14
1986	1.02	0.01	1.30	0.31	0.75	0.00	0.33	0.02	0.17	0.07	0.12	N/A	4.10
1987	1.21	0.02	1.42	0.27	0.64	0.01	0.21	0.02	0.17	0.01	0.13	N/A	4.11
1988	1.19	0.02	1.64	0.33	0.66	0.00	0.20	0.02	0.16	0.04	0.12	N/A	4.38
1989	1.55	0.02	1.44	0.25	0.53	0.00	0.22	0.02	0.15	0.02	0.12	N/A	4.32
1990	1.52	0.02	1.45	0.23	0.53	0.00	0.21	0.02	0.12	0.01	0.13	N/A	4.26
1991	1.71	0.01	1.57	0.24	0.59	0.00	0.22	0.02	0.13	0.01	0.14	N/A	4.63
1992	1.63	0.01	1.61	0.21	0.80	0.00	0.34	0.02	0.12	0.01	0.14	N/A	4.79

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Industrial Sector - Carbon Available for Combustion By Fuel Type (million tons Carbon)

Year	Bitum. Coal	Anthr. Coal	Natural Gas	Asphalt/ Road Oil	Fuel Oil	Kerosene	LPG	Lubes	Motor Resid Gas	Fuel	Other	Elec Losses	Elec	STATE TOTAL
1960	1.40	0.10	0.72	0.39	0.71	0.02	0.08	0.01	0.65	0.08	0.00	N/A	N/A	4.17
1965	1.58	0.09	1.10	0.39	0.72	0.02	0.14	0.01	0.60	0.05	0.06	N/A	N/A	4.76
1970	1.20	0.04	1.59	0.44	0.75	0.02	0.21	0.01	0.61	0.04	0.07	N/A	N/A	4.99
1971	0.89	0.03	1.64	0.47	0.74	0.02	0.21	0.01	0.49	0.03	0.10	N/A	N/A	4.65
1972	0.97	0.02	1.70	0.45	0.71	0.02	0.25	0.01	0.49	0.03	0.12	N/A	N/A	4.78
1973	0.98	0.02	2.13	0.39	0.72	0.02	0.29	0.01	0.55	0.04	0.13	N/A	N/A	5.28
1974	0.81	0.02	2.15	0.39	0.65	0.02	0.37	0.01	0.43	0.06	0.13	N/A	N/A	5.04
1975	0.80	0.03	1.95	0.35	0.60	0.01	0.39	0.01	0.43	0.04	0.12	N/A	N/A	4.71
1976	0.92	0.03	1.97	0.37	0.59	0.01	0.71	0.01	0.31	0.06	0.38	N/A	N/A	5.34
1977	0.89	0.03	1.80	0.38	0.61	0.01	0.68	0.01	0.27	0.08	0.48	N/A	N/A	5.23
1978	0.84	0.02	1.52	0.43	0.63	0.01	0.58	0.01	0.21	0.05	0.50	N/A	N/A	4.87
1979	1.03	0.02	1.89	0.48	0.86	0.03	0.60	0.01	0.19	0.10	0.59	N/A	N/A	5.80
1980	0.91	0.02	1.83	0.26	0.80	0.02	0.45	0.01	0.29	0.04	0.63	N/A	N/A	5.07
1981	0.89	0.03	1.84	0.30	0.55	0.02	0.38	0.01	0.33	0.01	0.28	N/A	N/A	4.64
1982	0.89	0.01	1.44	0.29	0.59	0.02	0.50	0.01	0.24	0.04	0.22	N/A	N/A	4.25
1983	0.90	0.01	1.38	0.24	0.49	0.00	0.45	0.01	0.10	0.03	0.20	N/A	N/A	3.81
1984	0.92	0.02	1.51	0.28	0.53	0.00	0.25	0.01	0.19	0.02	0.22	N/A	N/A	3.95
1985	1.02	0.01	1.40	0.30	0.61	0.00	0.33	0.01	0.19	0.03	0.21	N/A	N/A	4.12
1986	1.02	0.01	1.30	0.31	0.75	0.00	0.33	0.01	0.17	0.07	0.12	N/A	N/A	4.08
1987	1.21	0.02	1.42	0.27	0.64	0.01	0.21	0.01	0.17	0.01	0.12	N/A	N/A	4.09
1988	1.19	0.02	1.64	0.33	0.66	0.00	0.20	0.01	0.16	0.04	0.12	N/A	N/A	4.37
1989	1.55	0.02	1.44	0.26	0.53	0.00	0.22	0.01	0.15	0.02	0.12	N/A	N/A	4.30
1990	1.52	0.02	1.45	0.23	0.53	0.00	0.21	0.01	0.12	0.01	0.13	N/A	N/A	4.24
1991	1.71	0.01	1.57	0.24	0.59	0.00	0.22	0.01	0.13	0.01	0.14	N/A	N/A	4.62
1992	1.53	0.01	1.61	0.21	0.80	0.00	0.33	0.01	0.12	0.01	0.14	N/A	N/A	4.77

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Industrial Sector - Carbon Oxidized From Energy Uses (million tons Carbon)

Year	Bitum.		Anthr. Coal	Natural Gas		Asphalt/ Road Oil		Distillate Fuel		Kerosene	LPG	Motor Resid				Elec Losses	STATE TOTAL
	Coal	Gas		Gas	Gas	Road Oil	Fuel	Lubes	Gas			Fuel	Other	Elec			
1960	1.39	0.10	0.71	0.39	0.70	0.02	0.08	0.01	0.65	0.08	0.00	0.18	0.45	4.76			
1965	1.58	0.09	1.09	0.39	0.71	0.02	0.14	0.01	0.60	0.05	0.06	0.26	0.63	5.61			
1970	1.19	0.04	1.59	0.43	0.75	0.02	0.21	0.01	0.60	0.04	0.07	0.38	0.93	6.26			
1971	0.88	0.03	1.63	0.47	0.73	0.02	0.21	0.01	0.49	0.03	0.10	0.42	1.01	6.04			
1972	0.96	0.02	1.69	0.44	0.70	0.02	0.25	0.01	0.48	0.03	0.11	0.49	1.18	6.39			
1973	0.97	0.02	2.12	0.39	0.71	0.02	0.28	0.01	0.54	0.04	0.13	0.55	1.31	7.10			
1974	0.80	0.02	2.14	0.38	0.64	0.02	0.37	0.01	0.43	0.06	0.13	0.51	1.23	6.74			
1975	0.79	0.03	1.94	0.34	0.59	0.01	0.39	0.01	0.42	0.04	0.12	0.45	1.09	6.21			
1976	0.91	0.03	1.96	0.36	0.58	0.01	0.70	0.01	0.31	0.06	0.37	0.55	1.33	7.18			
1977	0.89	0.03	1.79	0.38	0.61	0.01	0.68	0.01	0.27	0.08	0.45	0.61	1.43	7.27			
1978	0.83	0.02	1.51	0.43	0.68	0.01	0.58	0.01	0.21	0.06	0.49	0.73	1.78	7.33			
1979	1.02	0.02	1.88	0.47	0.65	0.03	0.59	0.01	0.19	0.10	0.59	0.69	1.68	8.12			
1980	0.91	0.02	1.82	0.25	0.60	0.02	0.45	0.01	0.29	0.04	0.62	0.76	1.84	7.63			
1981	0.89	0.03	1.83	0.30	0.55	0.02	0.37	0.01	0.32	0.01	0.28	0.82	1.95	7.37			
1982	0.88	0.01	1.43	0.29	0.58	0.02	0.50	0.01	0.24	0.04	0.22	0.78	1.87	6.86			
1983	0.89	0.01	1.37	0.24	0.48	0.00	0.44	0.01	0.10	0.03	0.19	0.79	1.91	6.48			
1984	0.91	0.02	1.50	0.27	0.52	0.00	0.25	0.01	0.19	0.02	0.22	0.78	1.82	6.53			
1985	1.01	0.01	1.40	0.30	0.61	0.00	0.33	0.01	0.19	0.03	0.21	0.78	1.84	6.71			
1986	1.01	0.01	1.29	0.30	0.74	0.00	0.32	0.01	0.17	0.07	0.12	0.80	1.84	6.89			
1987	1.20	0.02	1.41	0.27	0.63	0.01	0.21	0.01	0.17	0.01	0.12	0.86	1.97	6.89			
1988	1.18	0.02	1.63	0.33	0.65	0.00	0.20	0.01	0.16	0.04	0.12	0.92	2.08	7.33			
1989	1.53	0.02	1.43	0.25	0.52	0.00	0.21	0.01	0.14	0.02	0.12	0.93	2.09	7.28			
1990	1.50	0.02	1.44	0.23	0.52	0.00	0.21	0.01	0.12	0.01	0.13	0.98	2.10	7.27			
1991	1.69	0.01	1.56	0.23	0.58	0.00	0.22	0.01	0.13	0.01	0.13	0.96	2.08	7.61			
1992	1.51	0.01	1.81	0.21	0.79	0.00	0.33	0.01	0.12	0.01	0.14	1.01	2.16	7.90			

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Industrial Sector - Carbon Dioxide Emissions From Energy Uses (million tons CO2)

Year	Blum. Coal	Anthr. Coal	Natural Gas	Asphalt/ Road Oil	Distillate Fuel	Kerosene	LPG	Lubes	Motor Resid Gas	Fuel	Other	Elec Losses	STATE TOTAL
1960	5.09	0.38	2.61	1.41	2.57	0.09	0.30	0.04	2.37	0.31	0.02	0.66	17.47
1965	5.74	0.33	4.01	1.40	2.61	0.06	0.50	0.04	2.19	0.19	0.23	0.96	20.57
1970	4.36	0.16	5.81	1.59	2.74	0.07	0.75	0.04	2.20	0.14	0.26	1.41	22.86
1971	3.22	0.12	5.99	1.71	2.89	0.08	0.77	0.04	1.79	0.12	0.38	1.53	22.13
1972	3.53	0.08	6.20	1.63	2.58	0.06	0.90	0.04	1.77	0.09	0.42	1.80	23.43
1973	3.56	0.07	7.76	1.43	2.52	0.07	1.04	0.05	2.00	0.16	0.46	2.01	28.03
1974	2.94	0.08	7.04	1.40	2.36	0.08	1.35	0.05	1.56	0.21	0.47	1.85	24.70
1975	2.09	0.10	7.13	1.26	2.17	0.03	1.41	0.03	1.55	0.15	0.43	1.65	22.79
1976	3.33	0.11	7.17	1.34	2.13	0.04	2.58	0.03	1.13	0.21	1.37	2.02	26.31
1977	3.24	0.10	6.55	1.40	2.22	0.03	2.49	0.04	0.99	0.29	1.56	2.24	26.55
1978	3.05	0.09	5.54	1.58	2.49	0.03	2.11	0.04	0.78	0.21	1.80	2.67	26.86
1979	3.74	0.08	6.89	1.73	3.13	0.09	2.18	0.04	0.71	0.35	2.16	2.55	29.78
1980	3.32	0.09	6.89	0.93	2.19	0.06	1.64	0.04	1.08	0.15	2.27	2.78	27.97
1981	3.25	0.12	6.72	1.08	2.00	0.08	1.37	0.04	1.18	0.03	1.03	3.00	27.03
1982	3.24	0.05	5.24	1.05	2.13	0.06	1.82	0.03	0.09	0.15	0.80	2.85	25.16
1983	3.28	0.05	5.02	0.88	1.77	0.02	1.63	0.04	0.38	0.10	0.71	2.91	23.78
1984	3.33	0.07	5.51	1.01	1.92	0.02	0.91	0.04	0.71	0.07	0.80	2.87	23.94
1985	3.70	0.05	5.12	1.11	2.23	0.02	1.20	0.04	0.69	0.09	0.76	2.87	24.59
1986	3.69	0.05	4.73	1.11	2.72	0.02	1.18	0.03	0.61	0.26	0.44	2.93	24.53
1987	4.40	0.07	5.18	0.98	2.31	0.02	0.77	0.04	0.61	0.05	0.45	3.16	25.26
1988	4.33	0.06	5.90	1.21	2.39	0.01	0.73	0.04	0.57	0.13	0.44	3.37	26.09
1989	5.61	0.06	5.25	0.93	1.91	0.01	0.79	0.04	0.53	0.00	0.43	3.41	26.69
1990	5.51	0.08	5.29	0.84	1.92	0.01	0.76	0.04	0.44	0.05	0.49	3.53	26.67
1991	6.19	0.05	5.71	0.80	2.14	0.01	0.80	0.04	0.47	0.04	0.49	3.51	27.92
1992	5.54	0.02	5.89	0.77	2.89	0.01	1.22	0.04	0.43	0.03	0.51	3.70	28.95
Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'													

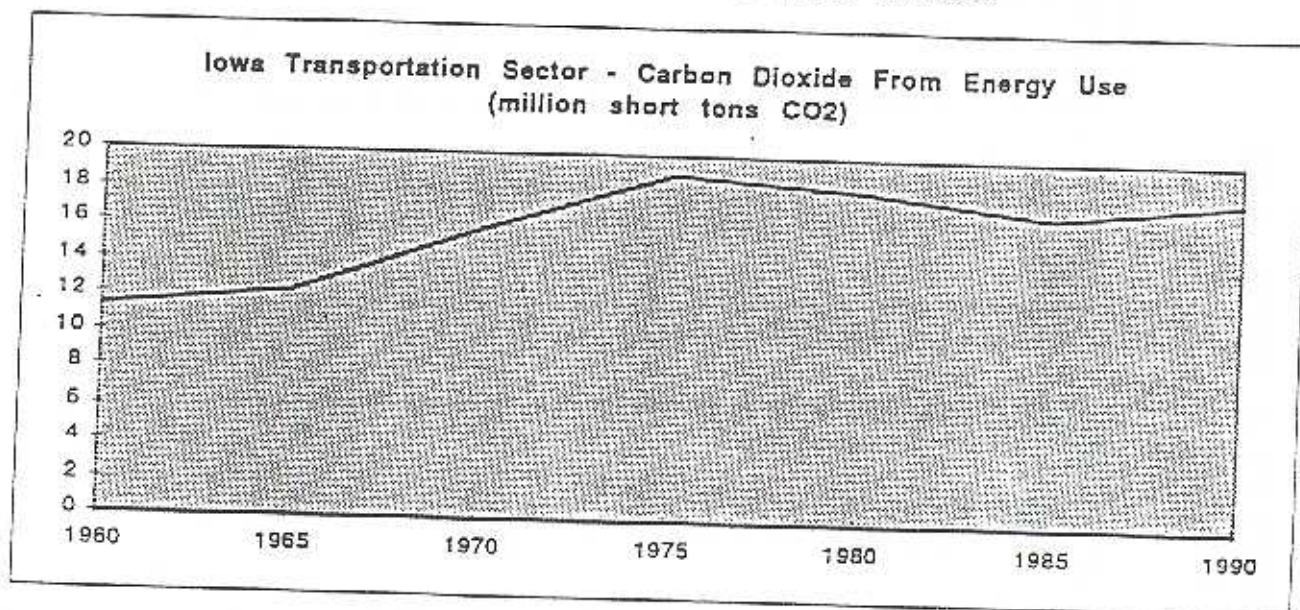
Iowa Industrial Sector - Carbon Oxidized From Energy Uses
(Million metric tons Carbon)

Year	Bitum. Coal	Anthr. Coal	Natural Gas	Asphalt/ Road Oil	Fuel Oil	Kerosene	LPG	Lubeg	Gas	Fuel	Motor Resid	Other	Elec. Losses	Elec. STATE TOTAL
1960	1.28	0.09	0.65	0.35	0.64	0.02	0.07	0.01	0.59	0.08	0.00	0.00	0.16	4.32
1965	1.42	0.08	0.99	0.35	0.65	0.02	0.12	0.01	0.54	0.05	0.06	0.06	0.24	5.09
1970	1.08	0.04	1.44	0.39	0.68	0.02	0.19	0.01	0.54	0.03	0.06	0.06	0.35	5.68
1971	0.80	0.03	1.48	0.42	0.67	0.01	0.19	0.01	0.44	0.03	0.09	0.09	0.38	5.48
1972	0.87	0.02	1.53	0.40	0.54	0.02	0.22	0.01	0.44	0.02	0.10	0.10	0.44	5.80
1973	0.88	0.02	1.92	0.35	0.55	0.02	0.26	0.01	0.49	0.04	0.11	0.11	0.50	6.44
1974	0.73	0.02	1.94	0.35	0.58	0.02	0.33	0.01	0.39	0.05	0.12	0.12	0.46	6.11
1975	0.72	0.03	1.78	0.31	0.54	0.01	0.35	0.01	0.38	0.04	0.11	0.11	0.41	5.64
1976	0.82	0.03	1.78	0.33	0.53	0.01	0.63	0.01	0.28	0.05	0.34	0.34	0.50	6.51
1977	0.80	0.03	1.62	0.35	0.55	0.01	0.62	0.01	0.24	0.07	0.41	0.41	0.55	6.59
1978	0.75	0.02	1.37	0.39	0.62	0.01	0.52	0.01	0.19	0.05	0.45	0.45	0.66	6.65
1979	0.93	0.01	1.70	0.43	0.77	0.02	0.54	0.01	0.17	0.09	0.53	0.53	0.63	7.37
1980	0.82	0.02	1.65	0.23	0.54	0.01	0.40	0.01	0.26	0.04	0.56	0.56	0.69	6.92
1981	0.80	0.03	1.66	0.27	0.50	0.01	0.34	0.01	0.29	0.01	0.25	0.25	0.74	6.69
1982	0.80	0.01	1.30	0.26	0.53	0.01	0.45	0.01	0.22	0.04	0.20	0.20	0.71	6.22
1983	0.81	0.01	1.24	0.22	0.44	0.00	0.40	0.01	0.09	0.03	0.18	0.18	0.72	5.88
1984	0.82	0.02	1.36	0.25	0.47	0.00	0.23	0.01	0.17	0.02	0.20	0.20	0.71	5.92
1985	0.92	0.01	1.27	0.27	0.55	0.00	0.30	0.01	0.17	0.02	0.19	0.19	0.71	6.08
1986	0.91	0.01	1.17	0.28	0.67	0.00	0.29	0.01	0.15	0.06	0.11	0.11	0.73	6.07
1987	1.09	0.02	1.28	0.24	0.57	0.01	0.19	0.01	0.15	0.01	0.11	0.11	0.78	6.25
1988	1.07	0.01	1.48	0.30	0.59	0.00	0.18	0.01	0.14	0.03	0.11	0.11	0.83	6.85
1989	1.39	0.01	1.30	0.23	0.47	0.00	0.19	0.01	0.13	0.02	0.11	0.11	0.84	6.60
1990	1.36	0.02	1.31	0.21	0.48	0.00	0.19	0.01	0.11	0.01	0.12	0.12	0.87	6.60
1991	1.53	0.01	1.41	0.21	0.53	0.00	0.20	0.01	0.12	0.01	0.12	0.12	0.87	6.91
1992	1.37	0.01	1.46	0.19	0.72	0.00	0.30	0.01	0.11	0.01	0.13	0.13	0.92	7.16

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Transportation Sector Trends

Emissions of CO₂ from the transportation sector have been relatively flat since the inception of the CAFE vehicle mileage standards in the early 1970s. The increasing efficiency of newer automobiles has acted to maintain emissions despite large increases in the number of vehicles and vehicle miles travelled.



Iowa Transportation Sector - Carbon Dioxide From Energy Use
(million short tons CO₂)

1960	11.37
1965	12.23
1970	15.9
1975	18.94
1980	18.21
1985	16.83
1990	17.97

Iowa Transportation Energy Consumption By State (Trillion Btu)

Year	Natural Aviation		Distillate		Jet		Motor			Resid		STATE	
	Gas	Gasoline	Fuel	Fuel	Fuel	LPG	Lubes	Gas	Fuel	Elhanol	TOTAL		
1960	9.2	1.8	10.0	1.0	0.1	3.1	123.4	1.4	0.0	0.0	150.0		
1965	11.2	1.0	11.6	1.3	0.2	2.9	132.5	0.1	0.0	0.0	161.6		
1970	18.5	1.3	25.3	4.1	0.2	2.9	157.8	0.2	0.0	0.0	210.3		
1971	20.5	1.3	30.8	3.7	0.3	2.4	171.5	0.0	0.0	0.0	230.0		
1972	20.5	1.2	32.9	4.1	0.2	2.6	177.4	0.0	0.0	0.0	238.9		
1973	16.7	0.5	33.1	4.0	0.2	3.1	193.9	0.0	0.0	0.0	256.5		
1974	17.4	1.2	39.6	4.2	0.2	2.9	182.4	0.0	0.0	0.0	245.9		
1975	16.2	1.0	39.9	4.7	0.2	3.0	183.5	0.0	0.0	0.0	248.5		
1976	8.9	1.0	43.3	5.4	0.2	3.4	195.0	0.1	0.0	0.0	257.3		
1977	7.0	1.0	46.3	5.6	0.2	3.2	197.7	0.1	0.0	0.0	261.1		
1978	4.9	1.1	45.3	6.3	0.3	3.4	198.7	0.0	0.0	0.0	260.0		
1979	10.8	1.0	51.4	5.9	0.1	3.6	186.5	0.0	0.0	0.0	259.3		
1980	12.7	0.9	46.2	4.6	0.1	3.2	170.4	0.0	0.0	0.0	239.1		
1981	10.9	0.8	43.1	4.0	0.4	3.0	162.8	0.0	0.1	0.1	225.1		
1982	8.9	0.6	51.0	3.6	0.4	2.8	160.1	0.0	0.4	0.4	227.8		
1983	8.0	0.6	46.1	3.3	0.4	2.9	164.0	0.0	0.4	0.4	225.7		
1984	10.7	0.4	50.8	3.4	0.5	3.1	159.1	0.0	0.3	0.3	228.3		
1985	10.5	0.4	46.8	3.3	0.3	2.9	155.1	0.0	0.3	0.3	219.6		
1986	7.3	0.8	46.2	3.3	0.5	2.8	155.4	0.0	0.3	0.3	216.6		
1987	8.2	0.6	50.8	4.4	0.2	3.2	156.9	0.1	0.3	0.3	224.7		
1988	10.7	0.7	51.8	4.0	0.2	3.1	161.8	0.0	0.3	0.3	232.6		
1989	10.6	0.8	53.5	4.2	0.2	3.1	163.0	0.0	0.3	0.3	235.5		
1990	9.2	0.5	56.3	5.0	0.2	3.2	159.1	0.0	0.3	0.3	233.8		
1991	6.7	0.4	49.2	5.0	0.2	2.9	160.6	0.0	0.3	0.3	225.3		
1992	7.0	0.4	51.2	4.5	0.2	3.0	157.7	0.0	0.4	0.4	224.4		

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Transportation Sector - Total Carbon Content By Fuel Type (million tons Carbon)

Year	Natural Gas	Aviation Gasoline	Distillate Fuel	Jet Fuel	LPG	Lubes	Motor Gas	Resid Fuel	Ethanol	STATE TOTAL
1960	0.15	0.04	0.22	0.02	0.00	0.06	2.84	0.03	0.00	3.16
1965	0.18	0.04	0.28	0.03	0.00	0.05	2.84	0.00	0.00	3.40
1970	0.30	0.03	0.58	0.09	0.00	0.05	3.38	0.00	0.00	4.41
1971	0.32	0.03	0.60	0.08	0.01	0.05	3.67	0.00	0.00	4.83
1972	0.33	0.02	0.72	0.09	0.00	0.05	3.80	0.00	0.00	5.01
1973	0.27	0.01	0.84	0.09	0.00	0.05	4.15	0.00	0.00	5.41
1974	0.28	0.02	0.85	0.09	0.00	0.05	3.90	0.00	0.00	5.20
1975	0.26	0.02	0.88	0.10	0.00	0.06	3.93	0.00	0.00	5.25
1976	0.14	0.02	0.95	0.12	0.00	0.06	4.17	0.00	0.00	5.48
1977	0.11	0.02	1.02	0.12	0.00	0.06	4.23	0.00	0.00	5.57
1978	0.08	0.02	1.00	0.14	0.01	0.08	4.25	0.00	0.00	5.56
1979	0.17	0.02	1.13	0.13	0.00	0.07	3.99	0.00	0.00	5.51
1980	0.20	0.02	1.02	0.10	0.00	0.06	3.65	0.00	0.00	5.05
1981	0.17	0.02	0.95	0.09	0.01	0.06	3.48	0.00	0.00	4.78
1982	0.14	0.01	1.12	0.08	0.01	0.05	3.43	0.00	0.01	4.85
1983	0.13	0.01	1.01	0.07	0.01	0.05	3.51	0.00	0.01	4.81
1984	0.17	0.01	1.12	0.07	0.01	0.06	3.40	0.00	0.01	4.85
1985	0.17	0.01	1.03	0.07	0.01	0.05	3.32	0.00	0.01	4.66
1986	0.12	0.02	1.02	0.07	0.01	0.05	3.33	0.00	0.01	4.62
1987	0.13	0.01	1.12	0.10	0.00	0.06	3.36	0.00	0.01	4.79
1988	0.17	0.01	1.14	0.09	0.00	0.06	3.46	0.00	0.01	4.94
1989	0.17	0.01	1.18	0.09	0.00	0.06	3.49	0.00	0.01	5.01
1990	0.15	0.01	1.24	0.11	0.00	0.06	3.40	0.00	0.01	4.98
1991	0.11	0.01	1.08	0.11	0.00	0.05	3.44	0.00	0.01	4.01
1992	0.11	0.01	1.13	0.10	0.00	0.06	3.37	0.00	0.01	4.79

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Transportation Sector - Carbon Available for Combustion By Fuel Type
(million tons Carbon)

Year	Natural Gas	Aviation Gasoline	Distillate Fuel	Jet Fuel	LPG	Lubes	Motor Gas	Resid Fuel	Ethanol	STATE TOTAL
1960	0.15	0.04	0.22	0.02	0.00	0.03	2.64	0.03	0.00	3.13
1965	0.18	0.04	0.26	0.03	0.00	0.03	2.84	0.00	0.00	3.37
1970	0.30	0.03	0.56	0.09	0.00	0.03	3.38	0.00	0.00	4.38
1971	0.32	0.03	0.68	0.08	0.01	0.02	3.67	0.00	0.00	4.80
1972	0.33	0.02	0.72	0.09	0.00	0.02	3.80	0.00	0.00	4.99
1973	0.27	0.01	0.84	0.09	0.00	0.03	4.15	0.00	0.00	5.38
1974	0.28	0.02	0.85	0.09	0.00	0.03	3.90	0.00	0.00	5.18
1975	0.26	0.02	0.88	0.10	0.00	0.03	3.93	0.00	0.00	5.22
1976	0.14	0.02	0.95	0.12	0.00	0.03	4.17	0.00	0.00	5.44
1977	0.11	0.02	1.02	0.12	0.00	0.03	4.23	0.00	0.00	5.54
1978	0.08	0.02	1.00	0.14	0.01	0.03	4.25	0.00	0.00	5.52
1979	0.17	0.02	1.13	0.13	0.00	0.03	3.99	0.00	0.00	5.48
1980	0.20	0.02	1.02	0.10	0.00	0.03	3.65	0.00	0.00	5.02
1981	0.17	0.02	0.95	0.09	0.01	0.03	3.48	0.00	0.00	4.75
1982	0.14	0.01	1.12	0.08	0.01	0.03	3.43	0.00	0.01	4.82
1983	0.13	0.01	1.01	0.07	0.01	0.03	3.51	0.00	0.01	4.78
1984	0.17	0.01	1.12	0.07	0.01	0.03	3.40	0.00	0.01	4.82
1985	0.17	0.01	1.03	0.07	0.01	0.03	3.32	0.00	0.01	4.64
1986	0.12	0.02	1.02	0.07	0.01	0.03	3.33	0.00	0.01	4.59
1987	0.13	0.01	1.12	0.10	0.00	0.03	3.36	0.00	0.01	4.75
1988	0.17	0.01	1.14	0.09	0.00	0.03	3.48	0.00	0.01	4.91
1989	0.17	0.01	1.18	0.09	0.00	0.03	3.49	0.00	0.01	4.98
1990	0.15	0.01	1.24	0.11	0.00	0.03	3.40	0.00	0.01	4.95
1991	0.11	0.01	1.08	0.11	0.00	0.03	3.44	0.00	0.01	4.78
1992	0.11	0.01	1.13	0.10	0.00	0.03	3.37	0.00	0.01	4.76

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Transportation Sector - Carbon Oxidized From Energy Uses (million tons Carbon)

Year	Natural Gas	Aviation Gasoline	Diesel Fuel	Jet Fuel	LPG	Lubes	Motor Gas	Residual Fuel	Ethanol	STATE TOTAL
1960	0.15	0.04	0.22	0.02	0.00	0.03	2.61	0.03	0.00	3.10
1965	0.18	0.04	0.25	0.03	0.00	0.03	2.81	0.00	0.00	3.33
1970	0.29	0.03	0.55	0.09	0.00	0.03	3.34	0.00	0.00	4.34
1971	0.32	0.03	0.67	0.08	0.01	0.02	3.63	0.00	0.00	4.75
1972	0.33	0.02	0.72	0.09	0.00	0.02	3.76	0.00	0.00	4.94
1973	0.27	0.01	0.83	0.09	0.00	0.03	4.11	0.00	0.00	5.33
1974	0.28	0.02	0.84	0.09	0.00	0.03	3.86	0.00	0.00	5.13
1975	0.26	0.02	0.87	0.10	0.00	0.03	3.89	0.00	0.00	5.17
1976	0.14	0.02	0.94	0.12	0.00	0.03	4.13	0.00	0.00	5.39
1977	0.11	0.02	1.01	0.12	0.00	0.03	4.19	0.00	0.00	5.48
1978	0.00	0.02	0.99	0.14	0.01	0.03	4.21	0.00	0.00	5.47
1979	0.17	0.02	1.12	0.13	0.00	0.03	3.95	0.00	0.00	5.42
1980	0.20	0.02	1.01	0.10	0.00	0.03	3.61	0.00	0.00	4.97
1981	0.17	0.02	0.94	0.09	0.01	0.03	3.45	0.00	0.00	4.70
1982	0.14	0.01	1.11	0.08	0.01	0.03	3.39	0.00	0.01	4.77
1983	0.13	0.01	1.00	0.07	0.01	0.03	3.47	0.00	0.01	4.73
1984	0.17	0.01	1.11	0.07	0.01	0.03	3.37	0.00	0.01	4.77
1985	0.17	0.01	1.02	0.07	0.01	0.03	3.29	0.00	0.01	4.59
1986	0.12	0.02	1.01	0.07	0.01	0.03	3.29	0.00	0.01	4.54
1987	0.13	0.01	1.11	0.09	0.00	0.03	3.32	0.00	0.01	4.71
1988	0.17	0.01	1.13	0.09	0.00	0.03	3.43	0.00	0.01	4.06
1989	0.17	0.01	1.17	0.09	0.00	0.03	3.45	0.00	0.01	4.93
1990	0.15	0.01	1.23	0.11	0.00	0.03	3.37	0.00	0.01	4.90
1991	0.11	0.01	1.07	0.11	0.00	0.03	3.40	0.00	0.01	4.73
1992	0.11	0.01	1.12	0.10	0.00	0.03	3.34	0.00	0.01	4.71

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Transportation Sector - Carbon Dioxide Emissions From Energy Uses
(million tons CO2)

Year	Natural Gas	Aviation Gasoline	Distillate Fuel	Jet Fuel	LPG	Lubes	Motor Gas	Resid Fuel	Ethanol	STATE TOTAL
1960	0.54	0.14	0.00	0.08	0.01	0.11	9.59	0.12	0.00	11.37
1965	0.65	0.14	0.03	0.10	0.01	0.10	10.29	0.01	0.00	12.23
1970	1.08	0.10	2.02	0.32	0.01	0.10	12.26	0.02	0.00	15.90
1971	1.16	0.10	2.46	0.29	0.02	0.08	13.32	0.00	0.00	17.43
1972	1.19	0.09	2.63	0.32	0.01	0.09	13.78	0.00	0.00	18.11
1973	0.97	0.04	3.04	0.32	0.01	0.11	15.08	0.00	0.00	19.55
1974	1.01	0.09	3.08	0.33	0.01	0.10	14.17	0.00	0.00	18.79
1975	0.94	0.06	3.19	0.37	0.01	0.10	14.25	0.00	0.00	18.94
1976	0.52	0.08	3.46	0.13	0.01	0.12	15.15	0.01	0.00	19.76
1977	0.41	0.08	3.70	0.14	0.01	0.11	15.36	0.01	0.00	20.11
1978	0.29	0.08	3.62	0.50	0.02	0.12	15.44	0.00	0.00	20.05
1979	0.63	0.08	4.10	0.47	0.01	0.12	14.49	0.00	0.00	19.89
1980	0.74	0.07	3.69	0.36	0.01	0.11	13.24	0.00	0.00	18.21
1981	0.53	0.06	3.44	0.32	0.03	0.10	12.65	0.00	0.01	17.24
1982	0.52	0.05	4.07	0.28	0.03	0.10	12.44	0.00	0.03	17.51
1983	0.47	0.05	3.68	0.26	0.03	0.10	12.74	0.00	0.03	17.35
1984	0.62	0.03	4.06	0.27	0.03	0.11	12.36	0.00	0.03	17.50
1985	0.81	0.03	3.74	0.26	0.02	0.10	12.05	0.00	0.03	16.83
1986	0.42	0.06	3.69	0.26	0.03	0.10	12.07	0.00	0.02	16.66
1987	0.40	0.05	4.06	0.35	0.01	0.11	12.19	0.01	0.02	17.27
1988	0.62	0.05	4.14	0.32	0.01	0.11	12.57	0.00	0.02	17.84
1989	0.62	0.05	4.27	0.33	0.01	0.11	12.60	0.00	0.02	18.07
1990	0.54	0.04	4.50	0.39	0.01	0.11	12.36	0.00	0.02	17.97
1991	0.39	0.03	3.93	0.39	0.01	0.10	12.48	0.00	0.03	17.36
1992	0.41	0.03	4.09	0.36	0.01	0.10	12.25	0.00	0.03	17.28

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

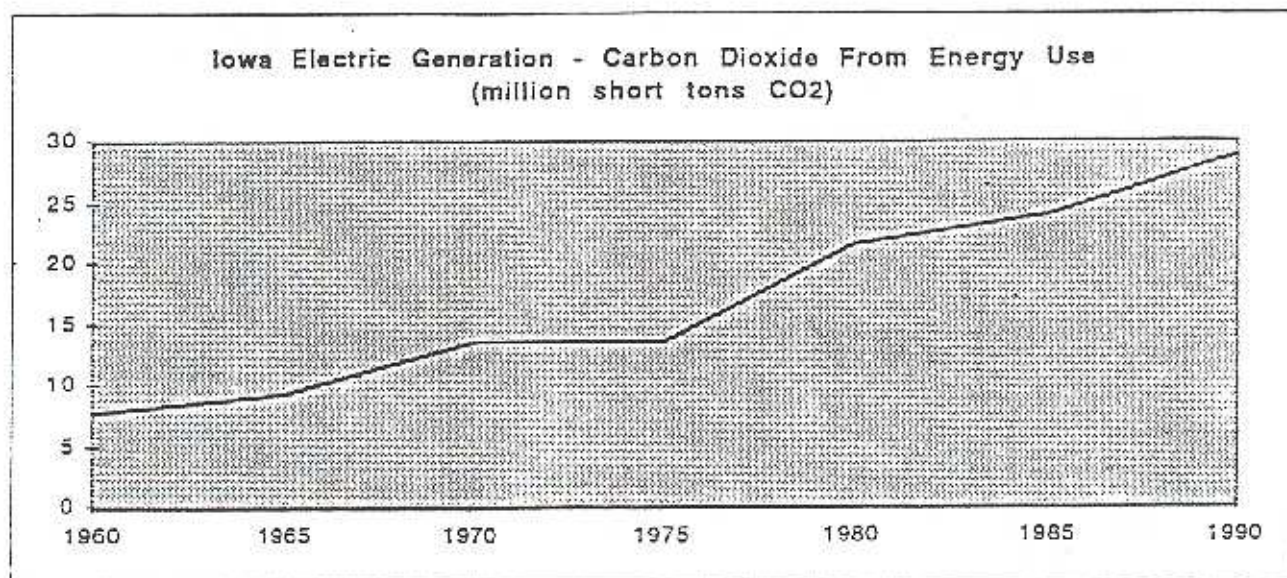
Iowa Transportation Sector - Carbon Oxidized From Energy Uses
(million metric tons Carbon)

Year	Natural Gas		Aviation Gasoline		Distillate Fuel		Jol Fuel		LPG	Lubeg	Motor Gas		Resid Fuel	Ethanol	STATE TOTAL	
	Gas	0.13	0.03	0.20	0.02	0.00	0.03	2.37	0.00	0.00	0.00	0.00	0.00	0.00	2.01	0.00
1960	0.13	0.03	0.20	0.02	0.00	0.03	2.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.01	0.00
1965	0.16	0.03	0.23	0.03	0.00	0.02	2.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.03	0.00
1970	0.27	0.02	0.50	0.08	0.00	0.02	3.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.94	0.00
1971	0.29	0.02	0.61	0.07	0.01	0.02	3.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.31	0.00
1972	0.30	0.02	0.65	0.08	0.00	0.02	3.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.48	0.00
1973	0.24	0.01	0.75	0.08	0.00	0.03	3.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.84	0.00
1974	0.25	0.02	0.78	0.08	0.00	0.02	3.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.65	0.00
1975	0.23	0.02	0.73	0.09	0.00	0.03	3.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.89	0.00
1976	0.13	0.02	0.86	0.11	0.00	0.03	3.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.89	0.00
1977	0.10	0.02	0.91	0.11	0.00	0.03	3.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.98	0.00
1978	0.07	0.02	0.90	0.12	0.01	0.03	3.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.96	0.00
1979	0.16	0.02	1.02	0.12	0.00	0.03	3.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.92	0.00
1980	0.18	0.02	0.91	0.09	0.00	0.03	3.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.51	0.00
1981	0.16	0.01	0.85	0.08	0.01	0.03	3.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.27	0.00
1982	0.13	0.01	1.01	0.07	0.01	0.02	3.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.33	0.00
1983	0.12	0.01	0.91	0.06	0.01	0.02	3.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.29	0.00
1984	0.15	0.01	1.00	0.07	0.01	0.03	3.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.33	0.00
1985	0.15	0.01	0.92	0.06	0.01	0.02	2.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.16	0.00
1986	0.11	0.01	0.91	0.06	0.01	0.02	2.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.12	0.00
1987	0.12	0.01	1.00	0.09	0.00	0.03	3.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.27	0.00
1988	0.15	0.01	1.02	0.08	0.00	0.03	3.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.41	0.00
1989	0.15	0.01	1.06	0.08	0.00	0.03	3.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.47	0.00
1990	0.13	0.01	1.11	0.10	0.00	0.03	3.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.45	0.00
1991	0.10	0.01	0.97	0.10	0.00	0.02	3.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.29	0.00
1992	0.10	0.01	1.01	0.09	0.00	0.03	3.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.28	0.00

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Trends in Electric Generation

The electric generation sector in Iowa has been the fastest growing greenhouse gas emitting sector of the Iowa economy. Since 1960 the trend has been steady increases in emissions, with exceptionally fast growth since 1980. This is a reflection of Iowa's growing dependence upon coal for electric generation.



Iowa Electric Generation - Carbon Dioxide From Energy Use
(million short tons CO₂)

1960	7.67
1965	9.32
1970	13.58
1975	13.66
1980	21.55
1985	24.06
1990	28.91

Annual Iowa Electric Utility Energy Inputs (Trillion Btu)

Year	Bltum. Coal	Anthr. Coal	Natural Gas	Heavy Oil	Light Oil	Petroleum Coke	Nuclear	Hydro	Geo- Thermal	Other	STATE TOTAL
1960	44.0	0.0	50.3	0.2	1.5	0.0	0.0	9.5	0.0	0.3	105.8
1965	58.6	0.0	52.8	0.2	1.1	0.0	0.0	9.7	0.0	0.3	122.7
1970	84.2	0.0	78.6	0.3	1.9	0.0	0.0	9.8	0.0	0.4	175.2
1971	90.8	0.0	72.0	0.7	2.2	0.0	0.0	9.5	0.0	0.5	175.5
1972	109.0	0.0	61.1	1.7	3.1	0.0	0.0	10.3	0.0	0.5	185.7
1973	112.6	0.0	62.1	0.9	1.5	0.0	0.0	9.4	0.0	0.5	187.0
1974	97.2	0.0	61.7	0.8	2.1	0.0	14.8	9.3	0.0	0.4	186.3
1975	100.6	0.0	47.3	1.3	3.0	0.0	25.2	9.1	0.0	0.4	186.9
1976	135.0	0.0	26.1	2.3	2.8	0.0	27.4	6.7	0.0	0.4	201.3
1977	151.9	0.0	13.0	2.1	3.2	0.0	31.1	9.1	0.0	0.2	210.4
1978	166.7	0.0	8.3	2.4	4.4	0.0	13.2	9.6	0.0	0.1	204.7
1979	176.0	0.0	8.4	2.1	2.9	0.2	31.4	9.3	0.0	0.0	230.9
1980	200.2	0.0	6.9	0.4	1.0	0.0	28.0	9.8	0.0	0.3	246.6
1981	215.9	0.0	3.4	0.0	1.0	0.0	24.3	10.2	0.0	0.2	255.0
1982	209.0	0.0	2.5	0.2	0.8	0.0	25.1	9.6	0.0	0.2	247.4
1983	218.0	0.0	3.3	0.1	0.8	0.0	25.2	9.7	0.0	0.5	257.6
1984	214.7	0.0	3.2	0.1	0.6	0.0	29.3	9.8	0.0	0.5	258.0
1985	227.3	0.0	2.1	0.0	0.6	0.0	20.8	21.4	0.0	0.8	272.8
1986	221.3	0.0	1.4	0.0	0.6	0.0	32.3	9.9	0.0	0.7	266.2
1987	237.9	0.0	3.0	0.0	0.7	0.0	27.2	10.1	0.0	0.7	279.9
1988	256.5	0.0	5.5	0.0	0.7	0.0	34.0	7.2	0.0	0.8	304.5
1989	261.0	0.0	2.4	0.0	0.7	0.0	33.7	6.9	0.0	0.2	304.9
1990	272.6	0.0	3.5	0.0	0.7	0.0	32.2	8.9	0.0	0.2	319.1
1991	281.8	0.0	3.7	0.0	0.6	0.0	44.5	9.1	0.0	0.2	339.9
1992	272.3	0.0	2.3	0.0	0.5	0.0	36.4	10.1	0.0	0.1	321.7

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Electric Utilities - Total Carbon Content By Fuel Type
(million tons Carbon)

Year	Ultum.		Anthr.		Natural		Heavy		Light		Petroleum		Nuclear	Hydro	Geo-		STATE TOTAL
	Coal	Gas	Coal	Gas	Oil	Oil	Oil	Oil	Oil	Oil	Coke	Coke			Thermal	Other	
1960	1.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.11
1965	1.70	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.57
1970	2.44	0.00	0.00	1.25	0.01	0.01	0.01	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.74
1971	2.62	0.00	0.00	1.15	0.02	0.02	0.02	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.84
1972	3.18	0.00	0.00	0.97	0.04	0.04	0.04	0.04	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.24
1973	3.26	0.00	0.00	0.99	0.02	0.02	0.02	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.30
1974	2.91	0.00	0.00	0.98	0.02	0.02	0.02	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.86
1975	2.91	0.00	0.00	0.75	0.03	0.03	0.03	0.03	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.76
1976	3.93	0.00	0.00	0.42	0.05	0.05	0.05	0.05	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.46
1977	4.40	0.00	0.00	0.22	0.05	0.05	0.05	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.74
1978	4.83	0.00	0.00	0.13	0.06	0.06	0.06	0.06	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.11
1979	5.11	0.00	0.00	0.13	0.05	0.05	0.05	0.05	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.37
1980	5.80	0.00	0.00	0.11	0.01	0.01	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.94
1981	6.25	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.33
1982	6.05	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.11
1983	6.31	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.38
1984	6.22	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.28
1985	6.58	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.63
1986	6.41	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.44
1987	6.89	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.96
1988	7.43	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.53
1989	7.56	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.61
1990	7.89	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.96
1991	8.16	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.23
1992	7.03	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.93

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Electric Utilities - Carbon Available for Combustion By Fuel Type (million tons Carbon)

Year	Bilum. Coal	Anthr. Coal	Natural Gas	Heavy Oil	Light Oil	Petroleum Coke	Nuclear	Hydro	Geo- Thermal	Other	STATE TOTAL
1960	1.27	0.00	0.80	0.00	0.03		0.00	0.00	0.00	0.00	2.11
1965	1.70	0.00	0.84	0.00	0.02		0.00	0.00	0.00	0.00	2.57
1970	2.44	0.00	1.25	0.01	0.04		0.00	0.00	0.00	0.00	3.74
1971	2.62	0.00	1.15	0.02	0.05		0.00	0.00	0.00	0.00	3.84
1972	3.16	0.00	0.97	0.04	0.07		0.00	0.00	0.00	0.00	4.24
1973	3.26	0.00	0.99	0.02	0.03		0.00	0.00	0.00	0.00	4.30
1974	2.91	0.00	0.98	0.02	0.05		0.00	0.00	0.00	0.00	3.88
1975	2.91	0.00	0.75	0.03	0.07		0.00	0.00	0.00	0.00	3.76
1976	3.93	0.00	0.42	0.05	0.06		0.00	0.00	0.00	0.00	4.46
1977	4.40	0.00	0.22	0.05	0.07		0.00	0.00	0.00	0.00	4.74
1978	4.83	0.00	0.13	0.06	0.10		0.00	0.00	0.00	0.00	5.11
1979	5.11	0.00	0.13	0.05	0.06		0.01	0.00	0.00	0.00	5.37
1980	5.80	0.00	0.11	0.01	0.02		0.00	0.00	0.00	0.00	5.94
1981	6.25	0.00	0.05	0.00	0.02		0.00	0.00	0.00	0.00	6.33
1982	6.05	0.00	0.04	0.00	0.02		0.00	0.00	0.00	0.00	6.11
1983	6.31	0.00	0.05	0.00	0.02		0.00	0.00	0.00	0.00	6.38
1984	6.22	0.00	0.05	0.00	0.01		0.00	0.00	0.00	0.00	6.28
1985	6.58	0.00	0.03	0.00	0.01		0.00	0.00	0.00	0.00	6.63
1986	6.41	0.00	0.02	0.00	0.01		0.00	0.00	0.00	0.00	6.44
1987	6.89	0.00	0.05	0.00	0.02		0.00	0.00	0.00	0.00	6.96
1988	7.43	0.00	0.09	0.00	0.02		0.00	0.00	0.00	0.00	7.53
1989	7.58	0.00	0.04	0.00	0.02		0.00	0.00	0.00	0.00	7.61
1990	7.89	0.00	0.08	0.00	0.02		0.00	0.00	0.00	0.00	7.96
1991	8.16	0.00	0.06	0.00	0.01		0.00	0.00	0.00	0.00	8.23
1992	7.88	0.00	0.04	0.00	0.01		0.00	0.00	0.00	0.00	7.93

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Electric Utilities - Carbon Oxidized From Energy Uses (million tons Carbon)

Year	Blum.		Anthr.		Natural		Heavy		Light		Petroleum		Nuclear	Hydro	Geo-		STATE
	Coal	Gas	Coal	Gas	Oil	Oil	Oil	Oil	Oil	Oil	Coke	Other			Thermal	Other	TOTAL
1960	1.26	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.09
1965	1.68	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.54
1970	2.41	0.00	0.00	1.25	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.70
1971	2.60	0.00	0.00	1.14	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.80
1972	3.12	0.00	0.00	0.97	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.20
1973	3.23	0.00	0.00	0.99	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.26
1974	2.79	0.00	0.00	0.90	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.82
1975	2.68	0.00	0.00	0.75	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.73
1976	3.09	0.00	0.00	0.41	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.41
1977	4.35	0.00	0.00	0.22	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.69
1978	4.78	0.00	0.00	0.13	0.06	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.03
1979	5.06	0.00	0.00	0.13	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.31
1980	5.74	0.00	0.00	0.11	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.88
1981	6.19	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.26
1982	5.99	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.05
1983	6.25	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.32
1984	6.15	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.22
1985	6.51	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.56
1986	6.34	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.38
1987	6.82	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.89
1988	7.35	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.45
1989	7.48	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.53
1990	7.91	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.98
1991	8.08	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.15
1992	7.80	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.85

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Electric Utilities - Carbon Dioxide Emissions From Energy Uses (million tons CO2)

Year	Bitum. Coal	Anthr. Coal	Natural Gas	Heavy Oil	Light Oil	Petroleum Coke	Nuclear	Hydro	Geo- Thermal	Other	STATE TOTAL
1960	4.62	0.00	2.93	0.02	0.12	0.00	0.00	0.00	0.00	0.00	7.67
1965	6.18	0.00	3.07	0.02	0.09	0.00	0.00	0.00	0.00	0.00	9.32
1970	8.85	0.00	4.57	0.03	0.15	0.00	0.00	0.00	0.00	0.00	13.58
1971	9.52	0.00	4.19	0.06	0.18	0.00	0.00	0.00	0.00	0.00	13.93
1972	11.45	0.00	3.58	0.15	0.25	0.00	0.00	0.00	0.00	0.00	15.39
1973	11.83	0.00	3.61	0.08	0.12	0.00	0.00	0.00	0.00	0.00	15.63
1974	10.21	0.00	3.59	0.07	0.17	0.00	0.00	0.00	0.00	0.00	14.02
1975	10.57	0.00	2.75	0.11	0.24	0.00	0.00	0.00	0.00	0.00	13.68
1976	14.25	0.00	1.52	0.20	0.22	0.00	0.00	0.00	0.00	0.00	16.18
1977	15.90	0.00	0.80	0.18	0.26	0.00	0.00	0.00	0.00	0.00	17.20
1978	17.52	0.00	0.40	0.21	0.35	0.00	0.00	0.00	0.00	0.00	18.56
1979	18.58	0.00	0.40	0.18	0.23	0.02	0.00	0.00	0.00	0.00	19.48
1980	21.04	0.00	0.40	0.03	0.08	0.00	0.00	0.00	0.00	0.00	21.55
1981	22.69	0.00	0.20	0.00	0.08	0.00	0.00	0.00	0.00	0.00	22.97
1982	21.96	0.00	0.15	0.02	0.06	0.00	0.00	0.00	0.00	0.00	22.19
1983	22.91	0.00	0.19	0.01	0.06	0.00	0.00	0.00	0.00	0.00	23.17
1984	22.56	0.00	0.19	0.01	0.05	0.00	0.00	0.00	0.00	0.00	22.80
1985	23.89	0.00	0.12	0.00	0.05	0.00	0.00	0.00	0.00	0.00	24.06
1986	23.28	0.00	0.08	0.00	0.05	0.00	0.00	0.00	0.00	0.00	23.39
1987	25.00	0.00	0.19	0.00	0.06	0.00	0.00	0.00	0.00	0.00	25.25
1988	26.96	0.00	0.32	0.00	0.06	0.00	0.00	0.00	0.00	0.00	27.33
1989	27.43	0.00	0.14	0.00	0.06	0.00	0.00	0.00	0.00	0.00	27.62
1990	28.85	0.00	0.20	0.00	0.06	0.00	0.00	0.00	0.00	0.00	28.91
1991	29.61	0.00	0.22	0.00	0.05	0.00	0.00	0.00	0.00	0.00	29.88
1992	28.62	0.00	0.13	0.00	0.04	0.00	0.00	0.00	0.00	0.00	28.79

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Electric Utilities - Carbon Oxidized From Energy Uses (million metric tons Carbon)

Year	Bitum.		Anthr.	Natural	Heavy		Light	Petroleum		Nuclear	Hydro	Geo-		STATE
	Coal	Coal		Gas	Oil	Oil	Oil	Coke				Thermal	Other	TOTAL
1960	1.14	0.00	0.00	0.72	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	1.90
1965	1.52	0.00	0.00	0.76	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	2.31
1970	2.19	0.00	0.00	1.13	0.01	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.00	3.36
1971	2.36	0.00	0.00	1.04	0.01	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.00	3.45
1972	2.83	0.00	0.00	0.88	0.04	0.04	0.06	0.00	0.00	0.00	0.00	0.00	0.00	3.81
1973	2.93	0.00	0.00	0.89	0.02	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	3.87
1974	2.53	0.00	0.00	0.82	0.02	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.00	3.47
1975	2.62	0.00	0.00	0.68	0.03	0.03	0.06	0.00	0.00	0.00	0.00	0.00	0.00	3.38
1976	3.53	0.00	0.00	0.38	0.05	0.05	0.06	0.00	0.00	0.00	0.00	0.00	0.00	4.01
1977	3.95	0.00	0.00	0.20	0.04	0.04	0.06	0.00	0.00	0.00	0.00	0.00	0.00	4.26
1978	4.33	0.00	0.00	0.12	0.05	0.05	0.09	0.00	0.00	0.00	0.00	0.00	0.00	4.59
1979	4.59	0.00	0.00	0.12	0.04	0.04	0.06	0.01	0.00	0.00	0.00	0.00	0.00	4.82
1980	5.21	0.00	0.00	0.10	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	5.33
1981	5.61	0.00	0.00	0.05	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	5.68
1982	5.43	0.00	0.00	0.04	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	5.49
1983	5.67	0.00	0.00	0.05	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	5.73
1984	5.58	0.00	0.00	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	5.64
1985	5.91	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	5.95
1986	5.75	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	5.79
1987	6.19	0.00	0.00	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	6.25
1988	6.67	0.00	0.00	0.08	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	6.76
1989	6.79	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	6.83
1990	7.09	0.00	0.00	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	7.15
1991	7.33	0.00	0.00	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	7.39
1992	7.08	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	7.12

Iowa Energy Data from Energy Information Administration, 'State Energy Data Report'

Iowa Electric Utilities - C & CO₂ Emissions Per Trillion BTU (Ions per TBTU)

Year	Total CO ₂ mill tons	Total C mill tons	TBTU Input	TBTU Delivered	CO ₂ /Input ton/TBTU	CO ₂ /Delivered ton/TBTU	C/Input ton/TBTU	C/Delivered ton/TBTU
1960	7.67	2.09	105.80	36.11	72,528	212,505	19,780	57,958
1965	9.32	2.54	122.70	41.88	75,962	222,567	20,717	60,700
1970	13.58	3.70	175.20	59.80	77,495	227,059	21,135	61,925
1971	13.93	3.80	175.50	59.90	79,351	232,496	21,641	63,408
1972	15.39	4.20	185.70	63.38	82,857	242,768	22,597	66,209
1973	15.63	4.26	187.00	63.82	83,562	244,835	22,790	68,773
1974	14.02	3.82	186.30	63.58	75,275	220,555	20,530	60,151
1975	13.66	3.73	186.90	63.79	73,099	214,179	19,936	58,412
1976	16.18	4.41	201.30	68.70	80,392	235,547	21,925	64,240
1977	17.20	4.60	210.40	71.81	81,741	239,499	22,293	65,318
1978	18.56	5.06	204.70	69.86	90,653	265,612	24,724	72,440
1979	19.48	5.31	230.90	78.81	84,363	247,183	23,008	67,413
1980	21.55	5.88	246.60	84.18	87,400	256,079	23,838	69,840
1981	22.97	6.26	255.00	87.03	90,081	263,876	24,562	71,966
1982	22.19	6.05	247.40	84.44	89,691	262,792	24,461	71,670
1983	23.17	6.32	257.60	87.92	89,958	263,576	24,534	71,884
1984	22.80	6.22	258.00	88.06	88,390	258,962	24,106	70,631
1985	24.00	6.56	272.80	93.11	88,184	258,377	24,050	70,467
1986	23.39	6.38	266.20	90.85	87,850	257,398	23,959	70,199
1987	25.25	6.89	278.90	95.53	90,204	264,296	24,601	72,081
1988	27.33	7.45	304.50	103.93	89,754	262,977	24,478	71,721
1989	27.62	7.53	304.90	104.08	90,597	265,448	24,708	72,395
1990	28.91	7.88	318.10	108.57	90,670	266,240	24,783	72,613
1991	29.88	8.15	339.90	118.01	87,897	257,536	23,972	70,237
1992	28.79	7.85	321.70	109.80	89,490	262,202	24,406	71,510

Iowa Energy Data from Energy Information Administration, State Energy Data Report

Greenhouse Gas Emissions From Production Processes

Industrial processes are not generally large contributors to greenhouse gas emissions, other than to the extent that fuel combustion is utilized in the process. This section of the State Workbook seeks to estimate the total greenhouse gas emissions from those few industrial processes that are known to emit greenhouse gases. In general, the calculation consists of application of an emission factor which relates emissions of the various greenhouse gases to certain units of production, such as tons of cement produced.

Greenhouse Gas Emissions from Production Processes, 1990

Process	Production Units	Emission Factor	Total CO2	Total N2O	Total PFC	Total HFC-23
			Emissions Tons	Emissions Tons	Emissions Tons	Emissions Tons
Cement Production						
Masonry	15,000 tons	0.0224	336			
Clinker	2,120,000 tons	0.5070	1,074,840			
@ Nitric Acid Production	0 tons	0.0055		0		
# Adipic Acid Production	0 tons	0.3000		0		
Lime Manufacture	2,750,000 tons	0.7850	2,158,750			
Limestone Use						
Calcite	15,000,000 tons	0.1200	1,800,000			
Dolomite	10,000,000 tons	0.1300	1,300,000			
Soda Ash Manufacture						
# Trona Production	0 tons	0.0974	0			
@ Soda Ash Consumption	0 tons	0.4150	0			
Carbon Dioxide Manufacture	416,500 tons	1.0000	0			
* Primary Aluminum Production	0 tons	0.0006			0	
# HCFC-22 Production	0 tons	0.0400				0
Total Emissions			6,553,926	0	0	0

@ Activity is known to occur, but data were not available.

It is not known that activity occurs.

* It is known that activity does not occur.

Methane Emissions From Natural Gas And Oil Systems

The State Workbook provided methodology for estimating methane emissions that were derived from crude oil and natural gas production, transport, and oil refining. Since the State of Iowa does not possess oil production or refining, or natural gas production, only an estimate of emissions from natural gas transport has been completed. Total state natural gas usage is determined from the Energy Information

Administration, State Energy Data Report, and is then multiplied by an emission factor developed by USEPA.

Iowa Methane Emissions from Natural Gas and Oil Systems, 1990

Natural Gas Consumed MMBtu	Emission Factor (lbs CH ₄ /MMBtu)			Emissions (Million tons CH ₄)		
	Low	High	Median	Low	High	Median
224,500,000	0.13230	0.27388	0.20309	0.01485	0.03074	0.02280

Iowa does not produce oil or gas, and there is no refining capacity in the state, therefore the natural gas consumption figures are the only calculations made here.

Methane Emissions From Coal Mining

The State of Iowa was once a substantial supplier of coal, however, the current production rate of coal continues to decline. Current mining operations are surface mines which in 1990 produced 381,000 short tons of coal (from 'Coal Data', by EIA, February 6, 1995).

Iowa Methane Emissions from Coal Mining, 1990

	Coal Production million short tons	Emissions cf/ton		Coefficient Methane million cf methane		Emitted
		Low	High	Low	High	
Underground Mines	0.000	N/A	N/A	0.000	0.000	
Surface Mines	0.381	3	10	1.143	3.810	
Post-Mining						
Underground	0.000	N/A	N/A	0.000	0.000	
Surface	0.381	10	16	3.810	6.096	
Total				4.953	9.906	
Average					7.430	
-Recovered					0.000	
Total (mil cf)					7.430	
Total (tons)					153.4935	

Coal production data are from the Energy Information Administration, 'Coal Data'

Methane Emissions From Landfills

Estimates of emissions of methane from Iowa landfills were accomplished using State Workbook methodologies and data collected from the Iowa Department of Natural Resources, Waste Bureau. The data collected are from calendar year 1990, which is the chosen baseline year for this study.

The first step in calculating emissions of methane from landfills in the state is to estimate the amount of waste-in-place, which USEPA has defined as waste that has been put into place over the past thirty years. Although waste generation and landfill data are not available for Iowa landfills for years prior to 1988, the current figures of 1990 were used to estimate waste-in-place per the USEPA methodology. This methodology is to take total waste landfilled in the state in 1990, multiply by 30 years, multiply by a waste generation rate (waste per capita) for 1990, apply the fraction of waste landfilled, and then finally apply a population correction factor. The population correction factor takes into account population growth rates over the previous thirty year period, as well as the changes in per capita waste generation over the same period. Since the Iowa population is essentially the same in 1990 as it was in 1960, this factor was estimated to be nearly one (0.99).

The next step in the calculation of methane emissions from landfills is to determine the amount of waste in place in large landfills versus waste in place in small landfills. A large landfill is defined in the State Workbook as having over 1.1 million tons of waste in place. However, using the limited Iowa data, an alternative USEPA number is used to determine the number of large landfills in Iowa. That guidance states that landfills receiving in excess of 100 tons per day are classified as large landfills (from conversation with IDNR officials). All others were assumed to be 'small' landfills for this study.

Methane emissions are estimated for both small and large landfills using the formulae provided in the workbook for non-arid states. (Since Iowa receives an average of over 25 inches of rainfall per year, it is considered a non-arid state). Once total methane emissions are estimated from these municipal solid waste landfills, a fraction, seven percent, is assumed to also emanate from industrial landfills, for which there is no state-maintained data. This seven percent is added to the total methane from MSW that was calculated earlier.

The final step is to account for methane that is flared or recaptured. Only two landfills in Iowa are known to be currently recapturing or flaring their landfill gas. The Cedar Rapids landfill and Polk County landfill are recapturing biogas, however, it is believed that recapture was not taking place during the 1990 baseline year for Polk County. Recaptured biogas from Cedar Rapids is estimated to be 500 million cubic feet per year and is provided to a nearby power plant.

Iowa Methane Emissions from Landfills, 1990

1990 Landfill Inputs

Large Landfills	1,290,141
Small Landfills	797,680
TOTAL Tonnage/yr	2,087,821
Large %	61.8
Small %	38.2

1990 Iowa Population	2,812,000
Waste Per Capita 1990	4.3 lbs/person day
Total Waste Generated	2,206,717 tons/year

Percent Waste Landfilled, 1990	94.6
Annual Growth Factor	0.99
Waste In Place = W *	62,008,23 tons waste in place

* Waste in place = 30 yrs * population * per capita waste/yr * % landfilled * growth factor / 2000 lbs/ton

W, Small Landfills	23.7 mil tons
W, Large Landfills	38.3 mil tons
Wa, Average Size Large Landfill	2,554,741. tons
Number of Large Landfills	15.0

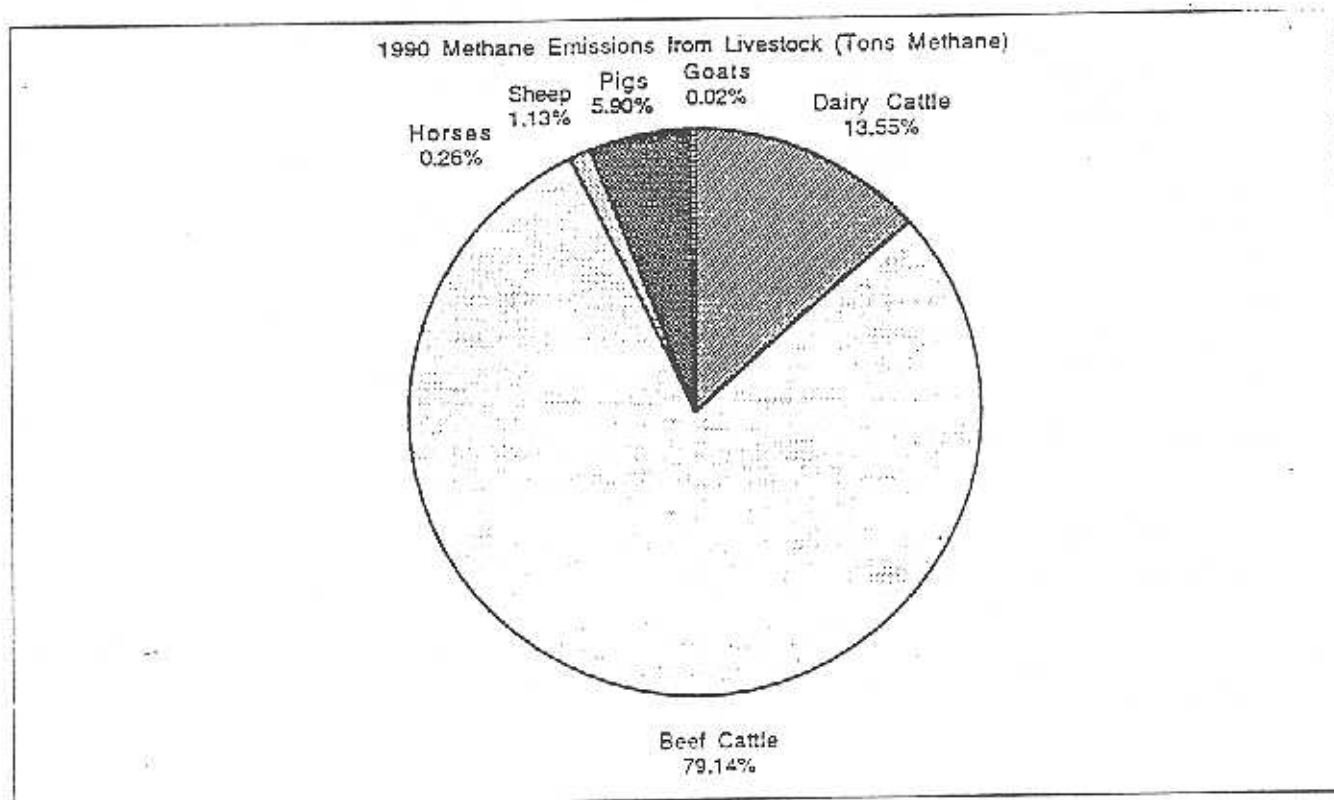
Methane Emission Calculations (Non-Arid Conditions)	Low	Avg	High
Small Landfills	0.35 * W + 20%	6,632,406	8,290,508
Large Landfills	N * (419000 + 0.26 Wa) + 15%	13,811,217	16,248,491
Gas Recaptured		1,369,863	1,369,863

Methane Emissions (tons/year)			
Small Landfills	51,247	64,059	76,870 ton CH4/yr
Large Landfills	106,716	125,548	144,380 ton CH4/yr
Total Methane MSW Landfills	157,963	189,606	221,250 ton CH4/yr
Total From Industrial Landfills	11,057	13,272	15,488 ton CH4/yr
Total	169,020	202,879	236,738
Adjustment from Flaring/Recovery	10,585	10,585	10,585
Adjustment for Oxidation	90.00	90.00	90.00 percent
Total NET METHANE from Landfills	142,592	173,065	203,538 ton CH4/yr
Total MMTCE	1.9963	2.4229	2.8495 MMTCE

Data From the Iowa Department of Natural Resources

Methane Emitted From Domesticated Animals

Estimates of methane emissions from animals have been conducted in accordance with the direction of the State Workbook. Animal population data for the baseline year of 1990 were obtained from Iowa Agricultural Statistics, a cooperative office of the U.S. Department of Agriculture (USDA) and the Iowa Department of Agriculture and Land Stewardship (IDALS). Some additional data were derived from the '1992 Census of Agriculture' published by the U.S. Department of Commerce and used to approximate 1990 numbers.



1990 Methane Emissions from Livestock (Tons Methane)	
Dairy Cattle	51,510
Goats	64.8
Beef Cattle	300,873.8
Sheep	431.2
Pigs	27,440
Horses	983.4

Calculations are conducted by multiplying an emission factor by the number of head of each animal category that contributes to methane emissions. The following tables fully present the calculations.

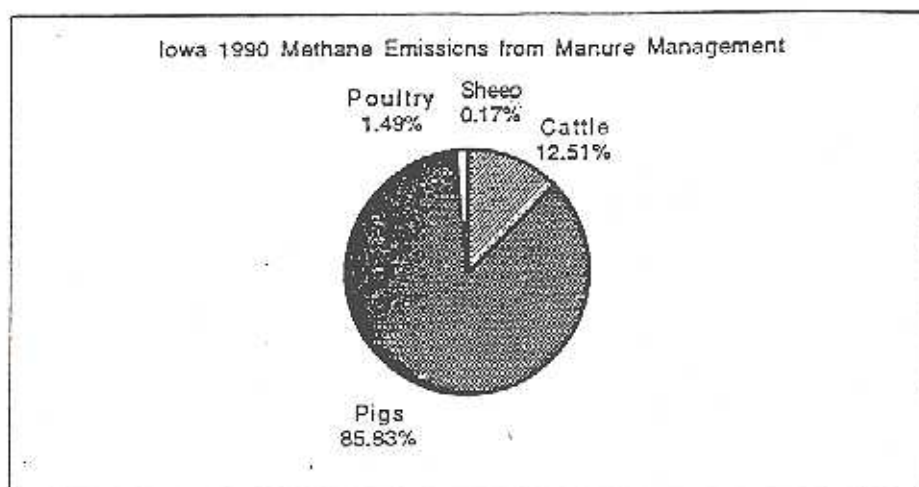
Methane Emissions From Domesticated Animals
(1990 populations)

Animal	Head	Pounds CH ₄ /head/yr	Total lbs CH ₄	Total tons CH ₄
Dairy Cattle				
Rep 0-12	0	240.7	0.0	0.0
Rep 12-24	120,000	240.7	28,884,000.0	14,442.0
Mature Cows	308,000	240.7	74,135,600.0	37,067.3
Beef Cattle				
Rep 0-12	0	130.9	0.0	0.0
Rep 12-24	155,000	130.9	20,289,500.0	10,144.8
Mature Cows	1,122,000	130.9	146,869,800.0	73,434.9
Weanling	915,000	130.9	119,773,500.0	59,886.8
Yearling	1,170,000	130.9	153,153,000.0	76,576.5
Bulls	1,235,000	130.9	161,661,500.0	80,830.8
Sheep	490,000	17.6	8,624,000.0	4,312.0
Goats	11,784	11.0	129,624.0	64.8
Pigs	13,600,000	3.3	44,880,000.0	22,440.0
Horses	47,681	39.6	1,888,167.6	944.1
Mules/Asses	1,619	48.5	78,521.5	39.3
TOTAL				380,183.6

Data from Iowa Department of Agriculture and Land Stewardship

Methane Emissions From Manure Management

Anaerobic decomposition of animal waste results in formation of methane. Manure management techniques, such as lagoon or pit storage, also have a strong effect on the amount of methane that is generated.



Iowa 1990 Methane Emissions from Manure Management
(Short Tons Methane)

Cattle	14908.4
Pigs	102318.9
Poultry	1772.7
Sheep	207.6

The calculation is conducted using animal population data obtained from Iowa Agricultural Statistics, and from the '1992 Census of Agriculture' published by the U.S. Department of Commerce. The population of each type of cattle, swine and poultry, as well as horses, mules, sheep, goats, and donkeys, are multiplied by USEPA-provided emission factors to estimate the total amount of volatile solids produced. The prevalence of manure management systems was then estimated from USEPA data to determine tons of volatile solids managed under each type of system. Another USEPA factor is then used to convert pounds of volatile solids into cubic feet of methane released. - Calculations are presented fully in the following tables.

Manure Management Systems(1990 populations)

Animal	Head	Typical Volatile Solids		Total VS lbs	Manure Management Systems (%)						
		Animal Mass (lb)	lbs VS per lb animal		An. Lag	Liq Slurry	Daily Sprd	Solid Stor	Other		
Mature Dairy Cattle	308,000	1345	3.65	1,512,049,000	3.0	20.0	8.0	65.0	4		
Mature Non-Dairy Cattle					An. Lag	Drylot	Liq/Slur	Pasture	Other		
Female Beef Cows	1,122,000	1102	2.60	3,214,754,400	0.0	13.0	0.0	87.0	0		
Multiple Use Cows	1,160,000	794	2.60	2,394,704,000	0.0	13.0	0.0	87.0	0		
Breeding Bulls/Bullocks	75,000	1507	2.60	309,465,000	0.0	13.0	0.0	87.0	0		
Young Cattle											
Growing Calves	915,000	500	2.60	1,189,500,000	0.0	13.0	0.0	87.0	0		
Feedlot-Fed on High Grain	980,000	600	2.60	1,528,900,000	0.0	13.0	0.0	87.0	0		
Market Swine	11,920,000	101	3.10	3,732,152,000	An. Lag	Drylot	Plt St.<1 mo	Plt St.>1 mo	Other		
Breeding Swine	1,800,000	399	3.10	2,077,992,000	3.0	30.0	11.0	39.0	13		
Poultry					3.0	30.0	11.0	39.0	13		
Layers	11,182,652	4	4.40	171,904,995	An. Lag	Deep Plt	Liq/Slur	Other			
Broilers	1,749,205	2	6.20	16,267,607	Litter	Other		4.0	4.0		
Ducks	0	3	6.75	0	Litter	Range	Other				
Turkeys	3,138,512	6	3.32	78,148,949	Litter	Range	Other				
Sheep	490,000	154	3.35	253,545,600	Pasture	Other		0.0			
Goats	11,784	141	3.48	5,782,173	Pasture	Other		0.0			
Donkeys	1,019	651	3.65	3,906,080	Paddock	Pasture	Other	0.0			
Horses/Mules	47,681	992	3.65	172,643,365	Paddock	Pasture	Other	0.0			
				992	8.0	92.0					

Livestock data from Iowa Agricultural Statistics and the 1992 Census of Agriculture (U.S. Dept. of Commerce)

Total Volatile Solids Per Manure Management System(1990 populations)

Animal	Total Volatile Solids per					
	Manure Management System (mill lbs)					
	An. Lag	Liq Slurry	Daily	Spnd	Solid Slor	Other
Mature Dairy Cattle	45.361	302.410		120.964	982.832	50.482
Mature Non-Dairy Cattle	An. Lag	Drylot	Liq/Slur	Pasture	Other	
Female Beef Cows	0.000	417.918	0.000		2,796.835	0.000
Multiple Use Cows	0.000	311.312	0.000		2,083.392	0.000
Breeding Bulls/Bullocks	0.000	40.230	0.000		269.235	0.000
Young Cattle						
Growing	0.000	154.635	0.000		1,034.065	0.000
Feedlot-Fed on High Grain	0.000	198.744	0.000		1,330.056	0.000
	An. Lag	Drylot	Plt SL<1 mo	Plt SL>1 mo	Other	
Market Swine	111.965	1,119.646	410.537		1,455.539	485.180
Breeding Swine	62.340	623.398	228.579		810.417	270.139
Poultry						
Layers	An. Lag	Deep Plt	Liq/Slur	Other		
	3.438	154.714	6.876		6.876	
	Litter	Other				
Broilers	16.268	0.000				
	Litter	Range	Other			
Ducks	0.000	0.000	0.000			
	Litter	Range	Other			
Turkeys	70.149	0.000	0.000			
	Pasture	Other				
Sheep	253.546	0.000				
	Pasture	Other				
Goats	5.782	0.000				
	Paddock	Pasture	Other			
Donkeys	0.000	1.953	0.000			
	Paddock	Pasture	Other			
Horses/Mules	13.811	158.832	0.000			

Livestock data from Iowa Agricultural Statistics and the 1992 Census of Agriculture (U.S. Dept. of Commerce)

Maximum Potential Methane Emissions per Manure System (1990) (mil cu ft)

Animal	Maximum Potential Methane per Manure Management System (mil cu ft)					
	An. Lag	Liq Slurry	Daily Sprd	Solid Stor	Other	
Mature Dairy Cattle	174.108	1,161.254	464.501	3,774.074	232.251	
Mature Non-Dairy Cattle	An. Lag	Drylot	Liq/Slur	pasture	Other	
Female Beef Cows	0.000	1,136.737	0.000	7,607.395	0.000	
Multiple Use Cows	0.000	846.767	0.000	5,886.828	0.000	
Breeding Bulls/Bullocks	0.000	109.427	0.000	732.318	0.000	
Young Cattle						
Growing	0.000	420.007	0.000	2,814.833	0.000	
Feedlot-Fed on High Grain	0.000	540.584	0.000	3,617.752	0.000	
Market Swine	An. Lag	Drylot	Plt St.<1 mo	Plt St.>1 mo	Other	
Breeding Swine	843.093	8,430.931	3,091.342	10,960.211	3,653.404	
Poultry	359.700	3,597.004	1,318.902	4,676.105	1,558.702	
Layers	An. Lag	Deep Plt	Liq/Slur	Other		
	18.738	843.194	37.475	37.475		
Broilers	Litter	Other				
	78.247	0.000				
Ducks	Litter	Range	Other			
	0.000	0.000	0.000			
Turkeys	Litter	Range	Other			
	375.896	0.000	0.000			
Sheep	Pasture	Other				
	1,116.868	0.000				
Goats	Pasture	Other				
	44.638	0.000				
Donkeys	Paddock	Pasture	Other			
	0.000	10.332	0.000			
Horses/Mules	Paddock	pasture	Other			
	73.063	840.221	0.000			

Livestock data from Iowa Agricultural Statistics and the 1992 Census of Agriculture (U.S. Dept. of Commerce)

Total Methane Emissions per Manure System (mil cu ft)

Animal	Maximum Potential Methane per Manure Management System (mil cu ft)				
	An. Lag	Liq Slurry	Daily Spd	Solid Slor	Other
Mature Dairy Cattle	156.769	240.380	0.929	33.967	2.090
Mature Non-Dairy Cattle	An. Lag	Drylot	Liq/Slur	Pasture	Other
Female Beef Cows	0.000	12.504	0.000	68.467	0.000
Multiple Use Cows	0.000	9.314	0.000	51.001	0.000
Breeding Buller/Bullocks	0.000	1.204	0.000	6.591	0.000
Young Cattle					
Growing	0.000	4.627	0.000	25.333	0.000
Feedlot-Fed on High Grain	0.000	5.946	0.000	32.560	0.000
Market Swine	An. Lag	Drylot	Pll St.<1 mo	Pll St.>1 mo	Other
Breeding Swine	758.784	92.740	319.954	2,268.764	32.881
Poultry	323.730	39.567	136.506	967.954	14.028
Layers	An. Lag	Deep Plt	Liq/Slur	Other	
	16.864	15.471	7.757	0.337	
Broilers	Litter	Other			
	7.925	0.000			
Ducks	Litter	Range	Other		
	0.000	0.000	0.000		
Turkeys	Litter	Range	Other		
	37.590	0.000	0.000		
Sheep	Pasture	Other			
	10.052	0.000			
Goats	Pasture	Other			
	0.402	0.000			
Donkeys	Paddock	Pasture	Other		
	0.000	0.093	0.000		
Horses/Mules	Paddock	Pasture	Other		
	0.658	7.562	0.000		

Livestock data from Iowa Agricultural Statistics and the 1992 Census of Agriculture (U.S. Dept. of Commerce)

Total Methane Emissions per Manure System (tons)

Animal	Total Tons		Total Metric		Total Metric Tons C Equiv	Total Methane Emissions per Manure Management System (tons)							
	Methane	C Equiv	Tons	Metric		An. Lag	Liq	Slurry	Daily	Spnd	Solid	Stor	Other
Mature Dairy Cattle	8,964.9	197,227.4	8,132.9	178,923.5		3,237.3		4,963.8		19.2		701.4	43.2
Mature Non-Dairy Cattle						An. Lag	Drylot	Liq/Slur	Pasture				Other
Female Beef Cows	1,672.0	36,785.0	1,516.9	33,371.1		0.0		258.2		0.0		1,413.8	0.0
Multiple Use Cows	1,245.5	27,401.5	1,129.9	24,858.5		0.0		192.3		0.0		1,053.2	0.0
Breeding Bulls/Bullocks	161.0	3,541.1	146.0	3,212.4		0.0		24.9		0.0		136.1	0.0
Young Cattle													
Growing	618.7	13,610.9	561.3	12,347.7		0.0		95.5		0.0		523.1	0.0
Feedlot-Fed on High Grain	785.2	17,493.4	721.4	15,869.9		0.0		122.8		0.0		672.4	0.0
Market Swine						An. Lag	Drylot	Pit	St.<1 mo	Pit	St.>1 mo		Other
Breeding Swine	71,720.0	1,577,839.4	65,063.9	1,431,406.5		15,668.9		1,915.1		6,607.0		46,050.0	679.0
Poultry	30,593.9	673,175.3	27,759.1	610,700.6		6,685.0		817.1		2,818.9		19,988.2	289.7
Layers	834.9	18,367.3	757.4	16,662.7		An. Lag	Deep Pit	Liq/Slur	Other				
Broilers	161.6	3,554.8	146.6	3,224.9		Litter	Other			160.2		7.0	
Ducks	0.0	0.0	0.0	0.0		Litter	Range	Other		0.0			
Turkeys	776.2	17,077.0	704.2	15,492.1		Litter	Range	Other		0.0			
Sheep	207.6	4,566.5	180.3	4,142.7		Pasture	Other			0.0			
Goats	8.3	182.5	7.5	165.6		Pasture	Other			0.0			
Donkeys	1.9	42.2	1.7	38.3		Paddock	Pasture	Other		1.9		0.0	
Horses/Mules	169.7	3,734.1	154.0	3,387.6		Paddock	Pasture	Other		150.2		0.0	
Livestock data from Iowa Agricultural Statistics and the 1992 Census of Agriculture (U.S. Dept. of Commerce)													
TOTAL TONS METHANE	117,936	2,594,590	106,991	2,353,804									

Methane Emissions From Flooded Rice Fields

There is no rice production in the state of Iowa that would result in methane emissions to the atmosphere.

Emissions from Agricultural Soil Management

Estimates of emissions of Nitrous Oxide (N_2O) are made by collecting nitrogen fertilizer application data and performing a mass balance on the nitrogen content. The fertilizer application data was collected from the Iowa Department of Agriculture and Land Stewardship (IDALS) for three years, centered on the baseline year of 1990. This was done to minimize year-to-year variations in fertilizer application.

The total amount of nitrogen applied, by each fertilizer type, is calculated from the IDALS data and an emission factor of 0.01117 pounds of N_2O -N per pound of nitrogen is calculated. A molecular weight ratio is then applied to estimate nitrous oxide emissions. The calculations are fully presented in the following table.

Nitrous Oxide Emissions From Iowa Fertilizer Usage, 1990(avg)

	Avg '89-'91	Tons/yr Nitrogen %	Total Nitrogen tons	N2O-N Emissions tons	N2O Emissions tons
Anhydrous Ammonia	634,870	82	520,593	6,090.9	9,571.5
Ammonium Nitrate	26,401	33.5	8,844	103.5	162.6
Ammonium Sulfate	8,906	21	1,870	21.9	34.4
Ammonium Thiosulfate	8,449	14	1,183	13.8	21.7
Urea	176,747	46	81,304	951.3	1,494.8
Nitrogen Solution 28%	511,608	28	143,250	1,676.0	2,633.8
Nitrogen Solution 30%	1,544	30	463	5.4	8.5
Nitrogen Solution 32%	159,098	32	50,911	595.7	936.0
Ammonium Phosphates					
08-24-00 liquid	9,718	8	777	9.1	14.3
10-30-00 liquid	10,187	10	1,019	11.9	18.7
10-34-00 liquid	42,735	10	4,274	50.0	78.6
11-37-00	1,131	11	124	1.5	2.3
11-52-00 dry	87,474	14	9,622	112.6	176.9
18-46-00 dry	398,599	18	71,748	839.4	1,319.1
Triple Super Phosphate	36,380	0	0	0.0	0.0
Phosphoric Acid	1,541	0	0	0.0	0.0
Muriate of Potash	688,779	0	0	0.0	0.0
Mixtures and Suspensions					
02-06-35 suspens	18,828	2	377	4.4	6.9
03-09-27	1,327	3	40	0.5	0.7
03-10-30 suspens	26,857	3	806	9.4	14.8
04-10-10 liquid	3,843	4	154	1.8	2.8
06-18-06 liquid	1,817	6	109	1.3	2.0
07-21-07 liquid	19,400	7	1,358	15.9	25.0
07-23-05 liquid	3,769	7	264	3.1	4.9
09-18-09 liquid	4,829	9	435	5.1	8.0
05-20-35 dry	1,618	5	81	0.9	1.5
06-24-24 dry	12,300	6	738	8.6	13.6
08-32-16 dry	4,088	8	327	3.8	6.0
09-23-30 dry	6,577	9	592	6.9	10.9
10-20-20	337	10	34	0.4	0.6
10-26-26 dry	1,744	10	174	2.0	3.2
23-09-12 dry	1,583	23	364	4.3	6.7
20-10-10	371	20	74	0.9	1.4
Totals					16,580.9

Fertilizer application data from Iowa Department of Agriculture and Land Stewardship

Greenhouse Gas Emissions From Forest Management and Land-Use Change

Attempts at calculating net carbon dioxide emissions from forest management and land-use change were frustrated by a lack of information and questions concerning applicability of calculation methodologies to Iowa conditions. The table that follows is a brief summary of the calculation of net carbon stored in woody biomass growth, balanced by timber harvest and fuelwood consumption. The figures are presented for cursory examination. Their accuracy are in doubt at this time.

It is believed that reforestation will be a major mechanism that will assist Iowa in reaching a net balance of carbon emissions. Perennial biomass (trees and grasses) have a great advantage over row-crop annual agriculture, in terms of greenhouse gas emission balances, because they do not disturb the soil to the same extent and therefore decreasing soil respiration and release of CO₂. Crops of woody biomass could be managed to accumulate carbon, or as a non-fossil fuel source. In addition, planting of trees or other woody crops can have ecological benefits over row-crop agriculture by restricting runoff, controlling soil erosion, and providing habitat for native wildlife. It is hoped that further investigations will provide improved quantification methods for woody crop impacts on greenhouse gas emission balances.

Greenhouse Gas Emissions from Forest Management and Land-Use Changes 1990
CO₂ Flux from Changes in Forests and Other Woody Biomass Stocks

Area of Biomass/Forest Stocks (1000 acres)	Annual Growth Rate t dm/acre/yr	Annual Biomass Increment 1000 t dm/yr	Carbon Fraction Dry Matter t C/t dm	Total Carbon Uptake 1000 t C/yr
21000	20.3	426,300.0	0.5000	213,150.0

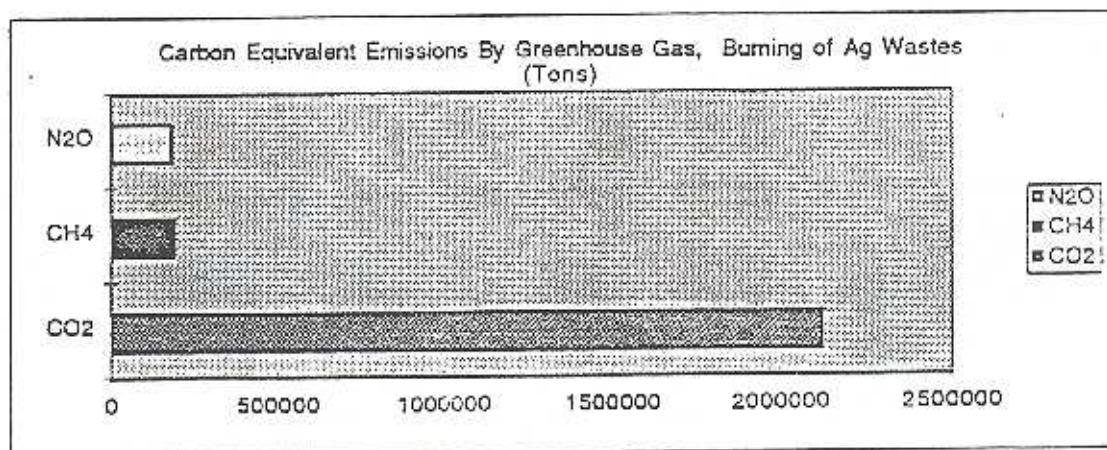
Number of Trees (1000 trees)	Annual Growth Rate (t dm/tree/yr)	Annual Biomass Increment 1000 t dm/yr	Carbon Fraction Dry Matter t C/t dm	Total Carbon Uptake 1000 t C/yr
566	0.4	229.8	0.5000	115
TOTAL				213,265

Amount of Commercial Timber Harvested (1000 cu ft/yr)	Biomass Conversion/ Expansion Ratio (t dm/cu ft)	Total Biomass Removed in Commercial Harvest (1000 t dm/yr)	Fuelwood Consumed (1000 t dm/yr)	Gross Biomass Consumed (1000 t dm/yr)	Wood Removed from Forest Clearing (1000 t dm/yr)	Net Biomass Consumption (1000 t dm/yr)
24700	16.0	395,200.0	16,000.0	411,216.0	0	411,216.0

Total Carbon Uptake 1000 t C/yr	Annual Carbon Released (1000 t C/yr)	Net Annual Carbon Uptake/Release (1000 t C/yr)	Net Annual CO ₂ Uptake/Release (1000 t C/yr)
213,264.9	205,608	-7,657	-28,075

Greenhouse Gas Emissions From Burning of Agricultural Crop Wastes

Data on crop production for the baseline year of 1990 were obtained from the office of Iowa Agricultural Statistics.



Carbon Equivalent Emissions By Greenhouse Gas, Burning of Ag Wastes (Tons)

CO ₂	2126804
CH ₄	187159
N ₂ O	177389

Crop production was then converted to units of weight produced, followed by estimation of carbon and nitrogen that is contained in the dry matter that is burned. Dry matter content by crop is provided by USEPA. Carbon contents and nitrogen/carbon ratios are also provided by USEPA in the State Workbook. Emissions of carbon dioxide, carbon monoxide, nitrous oxide, oxides of nitrogen are then estimated using release factors provided by USEPA. Final emission numbers are then converted from units of carbon or units of nitrogen to full molecular weights for each pollutant type. Calculations are presented fully in the following tables.

Iowa Emissions from Burning of Agricultural Crop Wastes,
1990 (avg)

Crop	Busbels	Pounds	Res/Crop Ratio	Residue Burned (%)	Dry Matter (%)	Fraction Burned (%)	Dry matter lbs DM
Corn	1,478,433.333	82,792,266.648	1.0	10.0	88.0	93.0	6,775,719.102
Wheat	2,788,333	167,299,980	1.3	10.0	91.1	93.0	18,426,403
Oats	38,683.333	1,237,866.656	1.3	10.0	90.6	93.0	135,590,219
Soybeans	333,428.333	20,005,699.980	2.1	10.0	88.7	93.0	3,465,609,414
Sorghum	368,516	22,110,960	3.0	10.0	90.0	93.0	14,805,499
Barley	357,287	17,149,776	1.2	10.0	90.4	93.0	1,730,179
Rye	49,014	2,744,784	1.6	10.0	90.0	93.0	367,581
Beans		3,211,800	2.1	10.0	88.7	93.0	556,384
Potatoes		21,033.333	0.4	10.0	86.7	93.0	678,375

Crop	Carbon	Total C	Fraction	Total C	lbs N/C	Ratio	Total	CH4	CH4	Emitted
	Content									
	% C/DM	Burned lbs C	(%)	CO2-C	lbs	N/C	Rel. (lbs N)	Ratio	tons	CH4-C
Corn	47.1	3,190,686.125	88.0	2,807,803,790	0.0172		48,294,225	0.003		4,211.7
Wheat	48.5	8,942.333	88.0	7,869,253	0.0082		64,528	0.003		11.8
Oats	48.5	65,801.933	88.0	57,905,701	0.0144		833,842	0.003		86.9
Soybeans	45.0	1,559,524.236	88.0	1,372,381,328	0.0511		70,128,686	0.003		2,058.6
Sorghum	48.5	7,185.109	88.0	6,322,896	0.0175		110,651	0.003		9.5
Barley	45.7	790.173	88.0	695,352	0.0026		1,808	0.003		1.0
Rye	48.5	178.387	88.0	156,981	0.0144		2,261	0.003		0.2
Beans	45.0	250,373	88.0	220,328	0.0511		11,259	0.003		0.3
Potatoes	42.3	286,681	88.0	252,280	0.0260		6,559	0.003		0.4

Crop	CO Emissions Ratio	CO Emmissions tons CO-C	N ₂ O Emissions Ratio	N ₂ O Emitted tons N ₂ O-N	NO _x Emissions Ratio	NO _x Emitted Tons NO _x -N
Corn	0.06	84,234	0.007	169.03	0.121	2,921.80
Wheat	0.06	236	0.007	0.23	0.121	3.90
Oats	0.06	1,737	0.007	2.92	0.121	50.45
Soybeans	0.06	41,171	0.007	245.45	0.121	4,242.79
Sorghum	0.06	190	0.007	0.39	0.121	6.69
Barley	0.06	21	0.007	0.01	0.121	0.11
Rye	0.06	5	0.007	0.01	0.121	0.14
Beans	0.06	7	0.007	0.04	0.121	0.68
Potatoes	0.06	8	0.007	0.02	0.121	0.40

Crop	Total CO2 Emissions tons CO2	Carbon Equivalent tons	Total CH4 Emissions tons CH4	Carbon Equivalent tons C E	Total N2O Emissions tons N2O	Carbon Equivalent tons C E	Total CO Emissions tons CO	Total NOx Emissions tons NOx
Corn	5,147,640	1,403,902	5,615.6	123,543	265.6	71,716.9	196,546	9,600.2
Wheat	14,427	3,935	15.7	346	0.4	95.8	551	12.8
Oats	106,160	28,953	115.8	2,548	4.6	1,238.3	4,053	165.8
Soybeans	2,516,032	686,191	2,744.8	60,385	385.7	104,141.1	96,067	13,940.6
Sorghum	11,592	3,161	12.6	278	0.6	164.3	443	22.0
Barley	1,275	348	1.4	31	0.0	2.7	49	0.4
Rye	288	78	0.3	7	0.0	3.4	11	0.4
Beans	404	110	0.4	10	0.1	16.7	15	2.2
Potatoes	463	126	0.5	11	0.0	9.7	18	1.3
Total	7,798,281	2,126,804	8,507	187,159	657	177,389	297,753	35,746

Total Carbon Equivalent Emissions 2.4914 MMTCE

Crop production data from Iowa Agricultural Statistics

Data for Sorghum, Barley, Rye, Beans, and Potatoes are averages of 1987 and 1992 data.

Methane Emissions From Municipal Wastewater

Emissions of methane from wastewater treatment have been estimated using the State Workbook methodology. General figures for biochemical oxygen demand (BOD5) were provided by USEPA on a per capita per day basis. This emission factor was then applied to the 1990 population to calculate total BOD5. USEPA also provided an emission factor to convert BOD5 treated anaerobically to methane. It was estimated that 15 percent of all wastewater treatment was performed anaerobically, and that 20 percent of that methane generated was then recaptured for flaring or energy uses. The 15 percent figure is a crude USEPA-provided estimate, and the 20 percent figure for recapture needs further investigation.

Iowa Methane Emissions from Municipal Wastewater, 1990

Population	Wastewater BOD Generation Rate lbs BOD5 per person per day	BOD Generated (lbs BOD5/yr)	Fraction Anaerobically Treated (%)	Quantity of BOD Treated Anaerobically (lbs BOD5/yr)	Methane Emission Factor CH4/lb BOD5	CH4 Emissions (lbs CH4)	Methane Emissions Recovered (lbs CH4)	Net CH4 Emissions (tons CH4)
2,812,000	0.1356	139,177,128	15	20,876,569	0.22	4,592,345	918,469	1,927

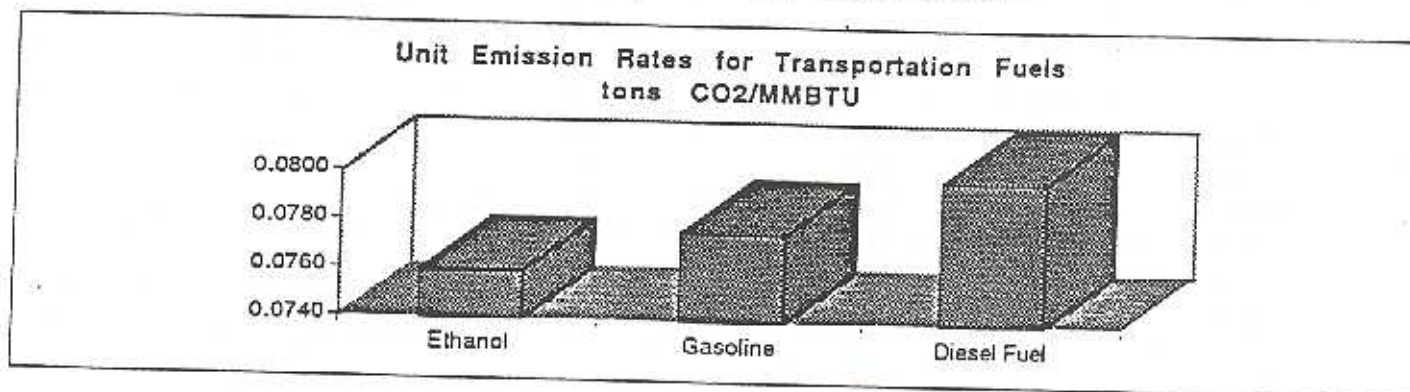
Default Values used for BOD5 Generation rate and fraction anaerobically treated

Preliminary Analysis of Greenhouse Gas Emissions From Ethanol

This simple analysis only presents the impact on greenhouse gas emissions from the transportation sector of using ethanol as a substitute for gasoline. Although emissions of greenhouse gases occurring during production and delivery of these

fuels are believed to be significant, no attempt is made to quantify emissions that occur during production of either ethanol or gasoline.

The values presented in the graph below are emission factors for carbon dioxide generation from fuel combustion for ethanol (0.076 tons CO₂/MMBTU), gasoline (0.0777 tons CO₂/MMBTU) and diesel fuel (0.0799 tons CO₂/MMBTU).



CONCLUSION

The methodology presented in the State Workbook is a large improvement over estimation techniques that were available as little as three years ago. The international acceptance of the estimation methodology makes it possible to have confidence that Iowa policy makers will be provided clear, consistent information from which to work and to gauge the success of particular efforts.

Despite the valuable improvements made in estimation techniques over recent years, there still remain a few areas for which poor data should be pointed out, because they may in fact be significant contributors to the equation governing the net balance of greenhouse gas emissions. The first is the relative lack of data concerning carbon sequestration by annual crop production. It may be possible that carbon and nitrogen uptake by the growing plants could effectively sequester a large portion of the emissions calculated within this report, greatly altering the balance of emissions on an annual basis. The second area of some concern is the difficulty with which estimates of greenhouse gas emissions are made from industrial processes as well as emissions of nitrous oxide and methane from combustion. Lastly, more in-depth analysis must be carried out to determine the impact of agriculture and woody biomass growth upon the net balance of Iowa greenhouse gas emissions.

Energy consumption is flat since 1980 but statewide CO₂ emissions are up due to increased coal combustion (which is more polluting than alternative fuels).

Carbon dioxide emissions per dollar of Gross State Product have decreased from 1985 indicating increased energy efficiency.

Iowans emit 29 tons of carbon dioxide per person per year.

Addressing energy consumption patterns likely holds the key to cost-effectively dealing with the emission of greenhouse gases.

The best strategy is to seek greater methods of energy efficiency in all economic sectors (industrial, commercial, transportation, residential, and utility).

Reforestation needs to be examined for its potential to sequester carbon dioxide emissions while providing other environmental benefits (wildlife habitat, erosion control, greenbelts, etc.). An additional strategy is to decouple greenhouse gas emissions from energy consumption by relying more on renewables (wind, biomass, solar, and hydropower) and nuclear power if problems with nuclear waste disposal and public acceptability can be solved.

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Appendix C

State Comparison Statistics

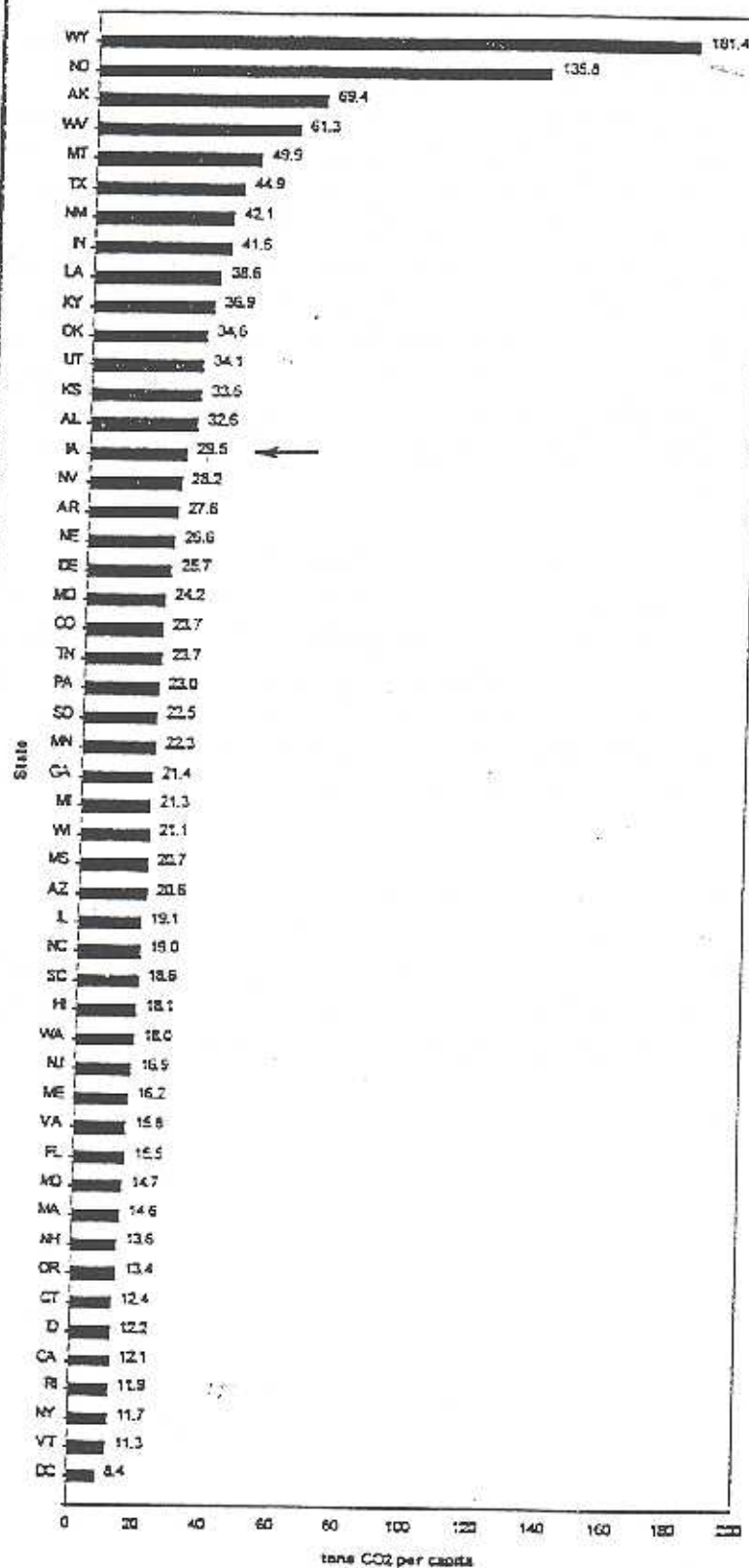
State Comparison Statistics

In order to provide a frame of reference for assessing the magnitude of Iowa greenhouse gas emissions estimated in this inventory, a comparison has been calculated using energy consumption data for the other 49 states and the District of Columbia. The following graphics are intended to provide estimates of the relative efficiencies found in each of the economic sectors analyzed by the Energy Information Administration, in the "State Energy Data Report, 1992". Direct comparisons of per capita emission rates are made to provide a rough basis for focusing future efforts. It must be stated, however, that in some instances, direct comparison of the data do not provide insight into all possible reasons for a particular showing. Demographics, for example, is a factor which plays a very important role in energy efficiency data for a state or even a country. Areas with dispersed populations are likely to be less energy efficient than highly concentrated areas such as New York City.

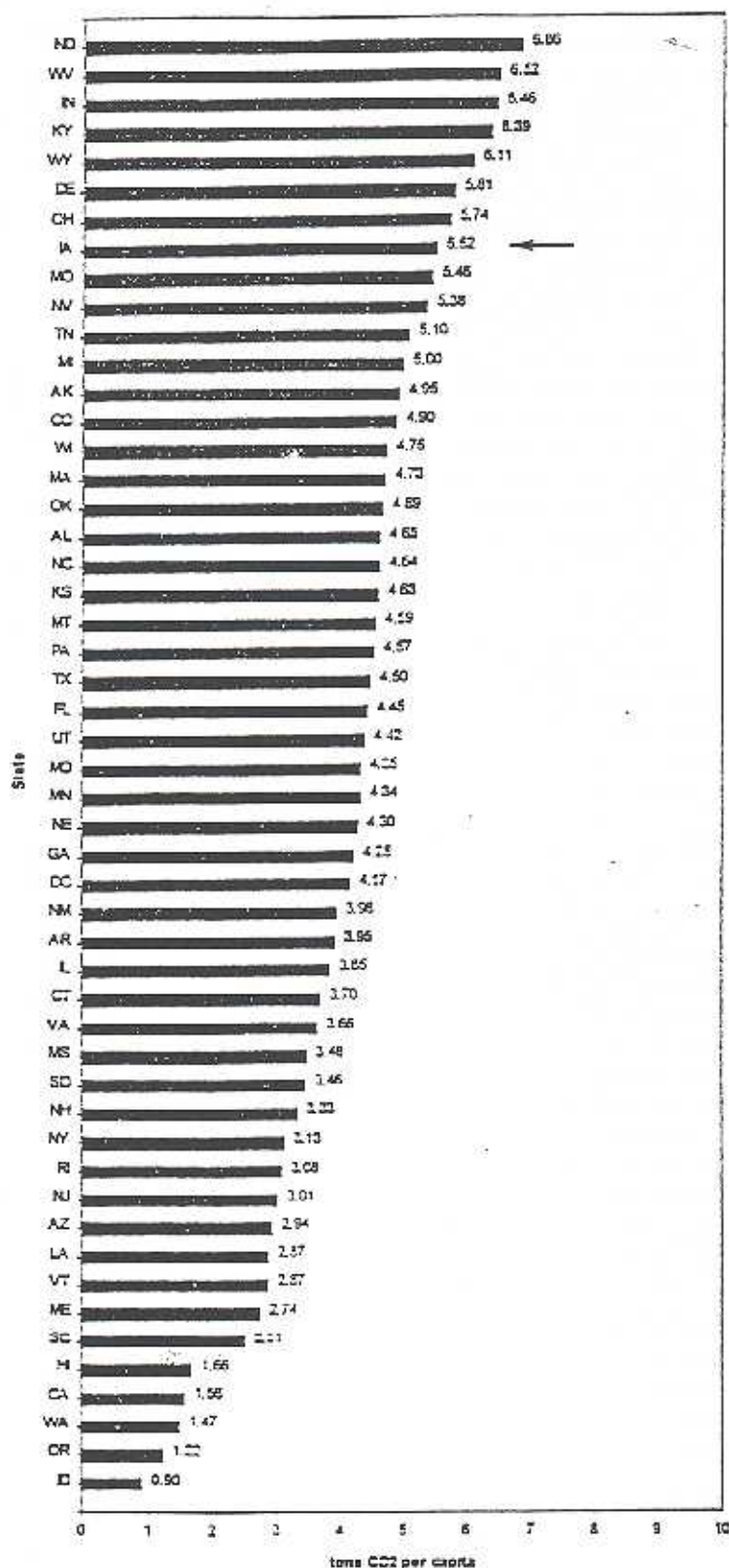
The rankings in the residential sector should be noted. Iowa has the 8th highest per capita emission of carbon dioxide from energy consumption. Relatively inexpensive utilities and old housing stock combine to produce less than efficient use of energy resources. The Iowa industrial sector is ranked 16th highest in per capita carbon dioxide emissions. The improvement in emissions per gross state product indicates a growing efficiency in the industrial sector. Further gains in efficiency will provide emission reductions along with cost savings and higher profits.

Surprisingly, Iowa ranked only 39th highest in transportation emissions per capita. Iowa has an older vehicle stock, and with the rural nature of the state, demographics would push the state toward less efficiency in this sector, given longer travel distances. The Iowa transportation sector will be studied in more detail under Phase II of the Global Climate Change Outreach Program.

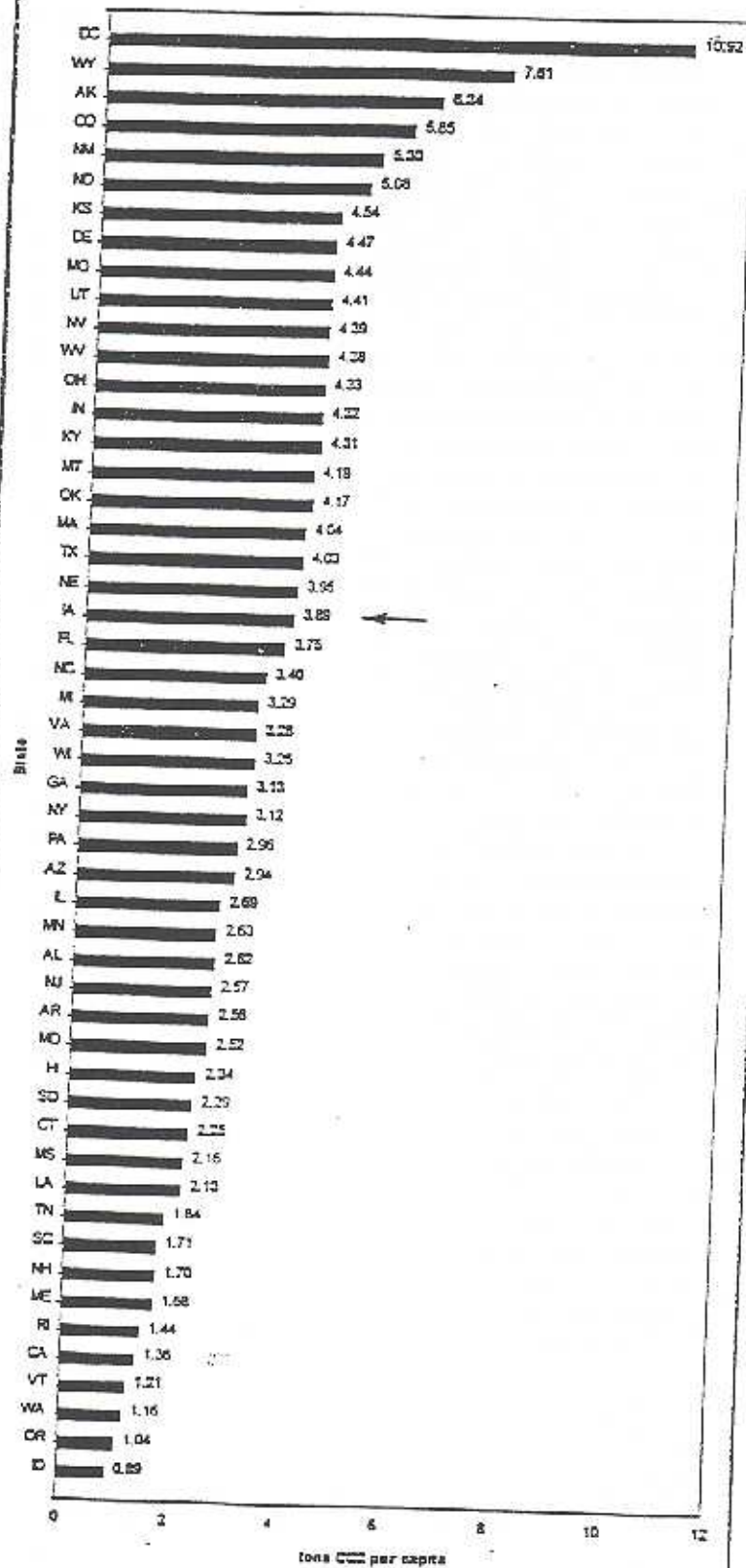
Per Capita CO2 Emissions per State



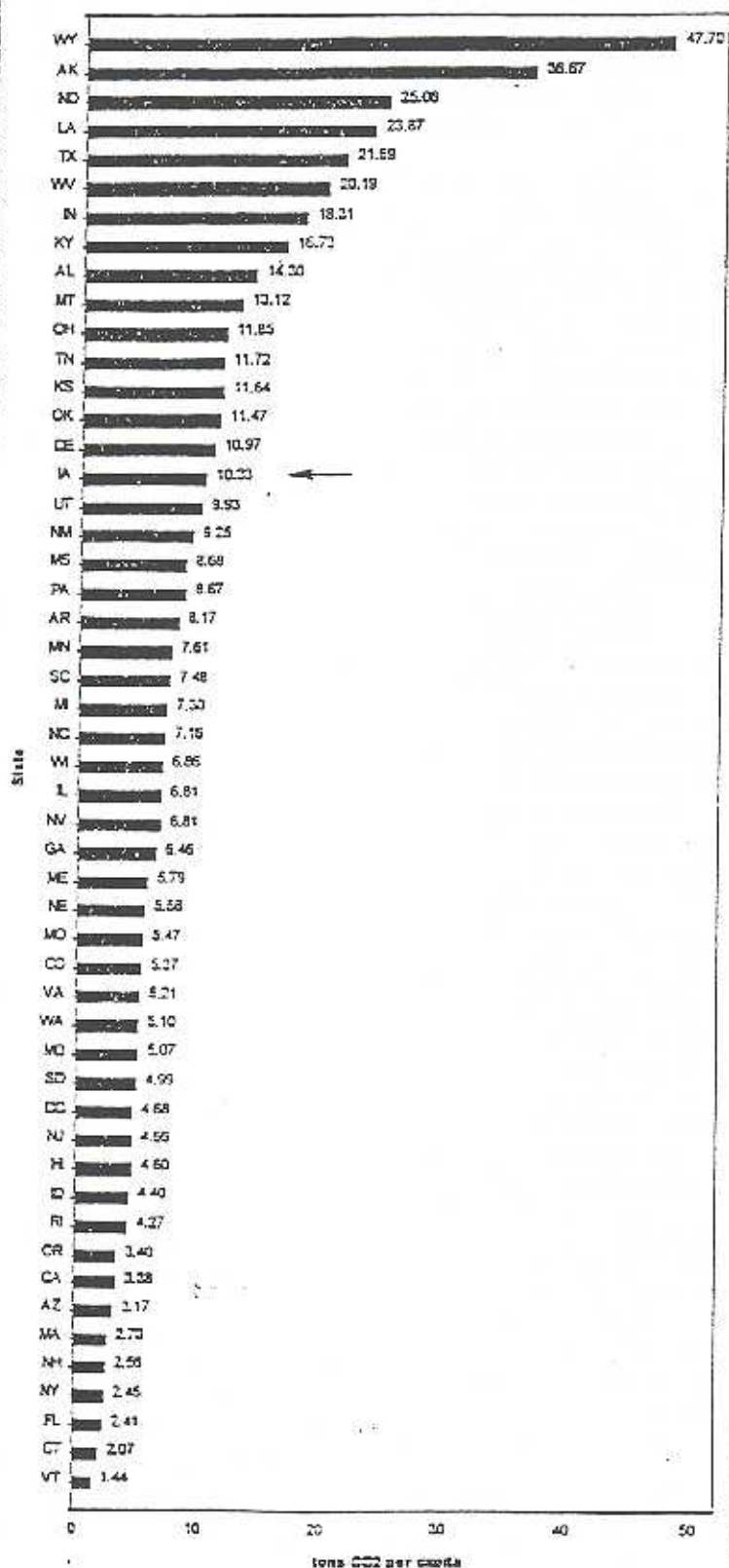
Residential Sector - Per Capita CO2 Emissions



Commercial Sector-Per Capita CO2 Emissions



Industrial Sector-Per Capita CO2 Emissions



Transportation Sector-Per Capita CO2 Emissions

